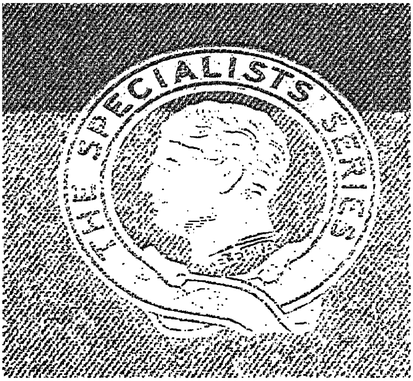
ELECTRIC LIFTS



PHILLIPS

Presented by

Prof. M.S. Thacker

to

P.E. Library

ELECTRIC LIFTS

PUBLISHED BY PITMAN

ELECTRICAL WIRING AND CONTRACTING

Edited by H. MARRYAT, M.I.E.E., M.I.Mech.E., assisted by Expert Contributors.

Vols. I. WORKSHOP SCIENCE, DRAWING, ELECTRICITY AND MAGNETISM. ALTERNATING CURRENT WORK.
II. D.C. GENERATORS AND MOTORS, MATHEMATICS. A.C GENERATORS AND MOTORS, MEASURING INSTRUMENTS AND TESTING, WIRES AND CABLES.
III. PRACTICAL WIRING WORK, SWITCHING, PRIMARY AND SECONDARY CELLS.
IV. MOTOR STARTERS AND REGULATORS, PRIVATE POWER PLANT, ELECTRIC SIGNS, ESTIMATING.
V. HEATING AND COOKING, CONVERTING PLANT, ELECTRIC BELL, ALARM AND CLOCK SYSTEMS.
VI. ELECTRIC LIFTS, LAMPS AND ILLUMINATION, HOUSE AND OFFICE TELEPHONES.
VII. RADIO INSTALLATION WORK, INDUSTRIAL WIRING WORK, THEATRE AND CINEMA INSTALLATION WORK.

In Seven Volumes. Each in crown 8vo, cloth gilt. **6s.** net.

POWER WIRING DIAGRAMS

By A. T. DOVER, M.I.E.E., A.Amer.I.E.E., *Head of the Electrical Engineering Department at the Battersea Polytechnic, London.*

A handbook of connection diagrams of control and protective systems for industrial D.C. and A.C. machines and apparatus.

In pocket size (6½ in. by 4 in.), foolscap 8vo, cloth, 216 pp., rounded edges, with 272 illustrations. Third Edition, Revised. **6s.** net.

ENGINEERING EQUIPMENT OF BUILDINGS

By A. C. PALLOT, B.Sc. (Eng.), Wh.Ex., A.M.I.E.E., A.M.I.H.V.E.

A descriptive survey of the most common items of engineering equipment installed in the up-to-date building. The range covered includes heating, lighting, ventilation, the electricity supply, and almost every electrical appliance—including lifts, lights, water supply, kitchen equipment, etc.

In demy 8vo, cloth gilt, 342 pp. **15s.** net.

PITMAN, Parker St., Kingsway, London W.C.2

ELECTRIC LIFTS

A MANUAL ON THE CURRENT PRACTICE IN THE INSTALLATION, WORKING, AND MAINTENANCE OF LIFTS

BY

R. S. PHILLIPS, A.M.I.E.E.
POWER ENGINEER, POST OFFICE ENGINEERING DEPARTMENT

LONDON
SIR ISAAC PITMAN & SONS, LTD.
1939

SIR ISAAC PITMAN & SONS, Ltd.
PITMAN HOUSE, PARKER STREET, KINGSWAY, LONDON, W.C.
THE PITMAN PRESS, BATH
PITMAN HOUSE, LITTLE COLLINS STREET, MELBOURNE

ASSOCIATED COMPANIES
PITMAN PUBLISHING CORPORATION
2 WEST 45TH STREET, NEW YORK
205 WEST MONROE STREET, CHICAGO
SIR ISAAC PITMAN & SONS (CANADA), Ltd.
(INCORPORATING THE COMMERCIAL TEXT BOOK COMPANY)
PITMAN HOUSE, 381–383 CHURCH STREET, TORONTO

MADE IN GREAT BRITAIN AT THE PITMAN PRESS, BATH
C8—(T.116)

PREFACE

MANY years have elapsed since the publication of a book dealing with British lift practice, and in view of the rapid development of the industry during recent years the Author feels that the present time is opportune for the production of a work describing modern lift equipment and methods.

The idea originated during the reading of the Author's paper entitled "Modern Electric Passenger Lifts" before the Institution of Post Office Electrical Engineers in 1935. Mention was made, during the discussion, of the lack of published information on the subject, whilst added weight was given to these remarks by subsequent talks with members of some of the lift manufacturing firms.

One of the difficulties encountered in preparing the material was the use, by various authorities interested in lift installation, of different terms for the same items of equipment and methods of control. The publication of the *Code of Practice for the Installation of Lifts and Escalators* by the Building Industries National Council, however, did much to remove these difficulties, and the Author decided to adopt, as far as possible, the terms recommended for general use by this Council. In addition, most of the safety measures embodied in the Code have been carried into this work.

A great deal of the information has been obtained from notes made by the Author during the past few years, whilst the origin of other details has been duly acknowledged in the text.

The value of the book has been considerably increased by the generous assistance rendered by the leading British lift and motor manufacturers who, in addition to supplying information regarding their equipment, were kind enough to loan blocks or photographs from which many of the illustrations have been prepared. In this connexion the Author desires to take this opportunity of thanking the following firms: British Thomson-Houston Co., Etchells, Congdon & Muir, Express Lift Co., J. & E. Hall, Marryat & Scott, Metropolitan Vickers Electrical Co., R. J. Shaw, Waygood Otis, Wm. Wadsworth, and in particular, Mr. W. Wood, Chief Electrical Engineer of the last-named firm, who checked a great deal of the material in Chapter XV and offered valuable suggestions. In preparing Chapter IV the Author gratefully acknowledges help received from Messrs. British Ropes, which firm loaned blocks for many of the illustrations in this chapter.

In conclusion, the Author wishes to state that, although employed by the Post Office, the practices described in this book are not necessarily those adopted by the Post Office Engineering Department. Obviously, however, many of the details are the result of experience gained during the erection and maintenance of Post Office lifts.

R. S. P.

LEEDS
1938

CONTENTS

PAGE

PREFACE v

CHAPTER I

PROVISION 1

Passenger lifts—Specification—Lifting ropes—Clearances for car and counterweight—Sheaves and pulleys—Car—Gates—Guides—Gearing—Safety devices—Wiring—Machine room—Counterweight—Control—Speed—Size and capacity of car—Type of control—Cost—Bank of lifts—Maximum running speed of cars—Rates of acceleration and retardation—Average number of stops made per journey—Average distance between stops—Time required for passengers to enter and leave the car—Goods lifts—Service lifts—Typical Installations

CHAPTER II

ACCOMMODATION 14

Well—Guarding—Machine room—Noise

CHAPTER III

TYPES OF DRIVES 26

Traction drive—Sheaves—Single-wrap drive—Double-wrap drive-Coefficient of friction—Diverting pulleys—Drum drive

CHAPTER IV

ROPING SYSTEMS AND ROPES 36

Methods of roping—Machine overhead—Machine below—Traction drives—Drum drives—Compensating ropes—Ropes—Material—Size—Lays—Factor of safety—Round strand ropes—Non-standard lift ropes—Ropes of special strand construction—Preformed ropes—Rope fastenings—Spliced ends—Bulldog clips—Sockets—Rope equalizing gear

CHAPTER V

PAGE
MOTORS 56

Lift motors: general—Size—Direct current motors—Motors for car speeds up to about 120 ft. per min.—Motors for car speeds between about 120 ft. per min. and 350 ft. per min.—Motors for car speeds above 350 ft. per min.—Alternating current motors—Polyphase supply—Motors for car speeds up to about 120 ft. per min.—Motors for car speeds between about 120 ft. per min. and 350 ft. per min.—Squirrel-cage induction motors—Slip-ring induction motors—Slip-ring variable voltage control—Tandem motors—A.c. commutator motors—Motors for car speeds above 350 ft. per min.—Single-phase supply—Motors for car speeds up to about 120 ft. per min.—Repulsion-induction motors—Capacitor motors—Motors for car speeds between 120 ft. per min. and 350 ft. per min.—Motors for car speeds above 350 ft. per min.

CHAPTER VI

VARIABLE VOLTAGE EQUIPMENT 83

Advantages—Speed regulation

CHAPTER VII

BRAKES 90

A.c. versus d.c. brakes—Torque motor brakes

CHAPTER VIII

GEARING 99

Worm gearing: over- and under-types —Irreversibility—Thrust races—Tandem gearing—Spur gearing

CHAPTER IX

CARS, COUNTERWEIGHTS, AND GUIDES 107

Passenger cars—Goods cars—Car flexible cable—Counterweights—Car and counterweight guides—Material—Sizes—Fixing and jointing

CHAPTER X

GATES, DOORS, AND LOCKS 126

Gates—Doors—Collapsible steel shutter door—Balanced rise-and-fall doors—Single-hinged door—Double-hinged door—Single-leaf slide—Two-leaf, two-speed slide—Two-leaf, centre opening slide—Two-leaf slide and stationary—Two-leaf slide and swing—Three-leaf, two-speed slide and stationary—Three-leaf, two-speed slide and swing—Four-leaf slide, two-speed centre opening—Methods of operation—Manually operated—Self-closing—Automatic operation—Semi-automatic operation—Power operation—Locks—Car gate or door locks—Car gate delayed contact—Landing gate or door locks—Lock requirements—Wiring of locks

CHAPTER XI

INDICATORS 154

Car indicators—Landing indicators—Directional indicators—Position indicators—

CHAPTER XII

SAFETY FEATURES 163

Car and counterweight safety gear—Instantaneous eccentric cam type—Gradual wedge clamp safety gear—Governor rope carriers—Governors—Flexible guide clamp safety gear—Safety gear stopping distances—Car and counterweight clearances—Terminal limit switches—Ultimate or final limit switches—Buffers—Spring buffers—Oil buffers—Spring return oil buffer—Gravity return oil buffer—Car emergency handle

CHAPTER XIII

FLOOR LEVELLING SYSTEMS 187

Direction switches—Floor selectors—Corrective levelling systems—The micro drive—The "Leveltric" system—Inductor and inducer systems

CHAPTER XIV

CAR CONTROL SYSTEMS 202

Simple car switch control—Pre-register—Departmental store control—Signal control—Automatic control—Semi-automatic control—Automatic collective control—Dual control—Automatic dispatching of cars

CHAPTER XV

CONTROLLERS 213

General—Dual voltage control system—Control features—Car switch controllers—Elementary car switch controller—Four-floor car switch controller with two-speed d.c. motor—Four-floor car switch controller with gearless motor and variable voltage control—Automatic controllers—Elementary automatic controller—Semi-automatic single-speed controller—Fully automatic two-speed controller with a.c. commutator motor—Fully automatic two-speed controller with tandem motor

CHAPTER XVI

PAGE
MAINTENANCE AND TESTING 250

Switches and fuses—Motor—Brake—Gearing—Sheaves and pulleys—Controller—Floor selector—Ultimate limit switch—Governor—Motor generator set and compressor—Ropes—General—Acceptance tests—Dead load tests—Energy consumption—Full load levelling—Irreversibility—Safety gear tests—Maximum speed—Car emergency handle—Lift balance—Levelling empty—Car and counterweight clearances—Car and landing gates—Controller—Acceleration and retardation—Terminal and ultimate limit switches

APPENDIX I

FACTORIES ACT, 1937: SECTIONS RELATING TO LIFTS . . 265

APPENDIX II

BRITISH STANDARD SIZES OF WIRE ROPES OF ROUND STRAND AND SPECIAL STRAND CONSTRUCTIONS . . . 269

APPENDIX III

BREAKING LOADS OF ROUND STRAND ROPES . . . 270

APPENDIX IV

BREAKING LOADS OF SPECIAL STRAND ROPES . . . 276

APPENDIX V

INTERFERENCE WITH WIRELESS RECEPTION DUE TO ELECTRIC LIFTS 280

INDEX 285

INSET

FIG. 53. PERFORMANCE CURVES OF B.T.-H. TYPE CH LIFT MOTOR . . . . . . *facing page* 75

ELECTRIC LIFTS

CHAPTER I

PROVISION

To provide the best possible lift service in a building, consistent with cost and any building restrictions, it is necessary that full consideration be given to the problem, and to do this all the available data regarding the type of building and its occupants should be closely studied. There are three main types of lifts, namely *passenger*, *goods*, and *service*. Passenger lifts are those designed primarily for passenger service, goods lifts are mainly for the transport of materials but may be required occasionally to carry passengers, whilst a service lift is so constructed as regards size, or otherwise, that it is impossible for passengers to enter the car, and hence goods only are carried. In any particular building it will soon be evident which of these types will be necessary, and some consideration will now be given to the selection of lifts for these various purposes.

PASSENGER LIFTS

The total capacity of passenger lifts required in any building to give a certain grade of service is determined by the number of occupants and the number of visitors who will be expected to utilize a lift service, and both vary considerably with the type of building. The density of the visitors and occupants will be great for restaurants and theatres and less for offices, hotels, and flats. In this country a large number of buildings are of such size and nature that very little difficulty will be experienced in deciding that one passenger lift will give adequate service. It should be remembered, however, that it is often preferable to install two small lifts if, on the grounds of capacity alone, it is thought that a single lift will have to be of a fairly large capacity, say 25 or 30 cwt. Two small lifts of 10 or 15 cwt. capacity each, will give better service than one large lift, the latter probably having been designed to cater for the maximum number of passengers at the periods of peak loading. Consequently, this lift will be running comparatively lightly loaded for most of the day, with a resulting decrease in efficiency and increase in running costs. On the other hand, with two small lifts, adequate service could probably be maintained during the greater part of the day with one lift, the second being brought into service during peak loads. The advantages to be gained by installing two smaller lifts often outweigh the extra initial outlay.

Having decided that the number of occupants and floors (usually not less than three floors for passenger service) justify the provision of a lift, it then becomes necessary to prepare a specification detailing the various features required. Although it is desirable from the safety point of view that certain items should be specified, the general type of passenger lift in this country is now so well established that most of the reputable lift firms will design and supply a perfectly satisfactory and safe lift if provided with only the main requirements such as well sizes, power supply characteristics, maximum car speed, type of control, and car capacity. The essential details can confidently be left to any British firm of repute if the buyer is not in a position to furnish a comprehensive specification. Those authorities, however, who draw up their own specifications in order to ensure that they obtain, even in detail, what they require, almost all specify certain main items of equipment and conditions to which they must conform. Extracts from a typical high-class specification are given here as a guide.

Specification. *Lifting Ropes.* Minimum number three, usually Lang's lay and having a factor of safety of not less than 15. No ropes to be lengthened or repaired by joints. Ropes to be fastened to the car frame so that all strain is removed from the car.

Clearances for Car and Counterweight. (Minimum values for these as stated in Chapter XII.)

Sheaves and Pulleys. Cast iron, of disc construction and of such diameters that none is less than fifty times the rope diameter. (Frequently, larger size sheaves and pulleys than this are specified in order to secure long rope life.) Any pulley or sheave shaft fitted between dead eyes to be reduced in diameter at the points of entry. (The angle of the sheave groove is usually that specified in B.S.S. No. 329, *Round Strand Steel Wire Ropes for Lifts and Hoists*, i.e. 42°.)

Car. General finish to suit the customer (but the minimum thicknesses for panelling and framing of wooden cars is often specified as $\frac{3}{4}$ in. and $1\frac{1}{2}$ in. respectively). Removable panel to be fitted either in the roof or in the side, the latter if two lifts run side by side in the same well. Car to be adequately ventilated and artificially lighted.

Gates. Of overhung collapsible type, the centres of the pickets to be not more than 5 in. apart when the gate is closed. Pickets of steel channel $\frac{5}{8}$ in. or $\frac{3}{4}$ in. wide. Mid bar or equivalent type, e.g. "Nu-bar," to be fitted to car. (This is also often specified for car and landings. In these mid-bar types the distance between the centres of the pickets is not more than 3 in. when the gate is closed.) The landing gates to be mechanically and electrically interlocked and car gate electrically interlocked only.

Guides. Of steel, either round or tee-section (the latter specified for car speeds above 200 ft. per min.). Round guides to be mounted on backings. Spacing of guide fixings to be not more than 4 ft. and 6 ft. for round and tee guides respectively.

Gearing. Worm and worm-wheel type. Worm of steel, forged solid with shaft, and wheel to consist of renewable phosphor bronze rim shrunk and bolted to a cast-iron centre. (The worm is frequently cut so that the gear is irreversible as a safety precaution.)

Safety Devices. Terminal limit switches to stop the car automatically at the terminal floors. In addition, ultimate limit switch to be fitted. Safety gear to be provided on both car and counterweight, the former to be fixed underneath the car. (Cam type safety gear for speeds up to 200 ft. per min., and either gradual wedge clamp type or flexible guide clamp type for higher speeds.) Buffers to be fitted under both car and counterweight (helical or volute spring buffers for speeds up to 300 ft. per min. and oil buffers for higher speeds.)

Wiring. All electrical wiring to be in accordance with the Regulations issued by The Institution of Electrical Engineers. In connexion with these, Regulation No. 122 of the *Regulations* *for the Electrical Equipment of Buildings*, which is as follows, should be noted.

Every lift or hoist operated electrically shall comply with the following requirements—

(*a*) It shall be operated from a circuit which is independent of the lighting installation.

(*b*) The multi-core trailing cable shall comprise the requisite number of conductors to keep the motor wiring and the control and safety devices entirely separate.

(*c*) The control and motor leads shall be in separate conduits.

(*d*) Except in special cases, such as chemical works or cold stores, all cables for any purpose in the lift or hoist shaft, except trailing cables, shall be armoured or shall be enclosed in metal conduits.

Machine Room. To be adequately lighted and ventilated and at least 7 ft. clear in height.

Counterweight. Sections to be of cast iron or cast iron weighted with lead and tie rods to pass through holes in all sections.

Control. Controller reversing switches to be mechanically and electrically interlocked. It must be impossible to operate the lift if any landing gate or car gate is open. It must be impossible to interfere with the travel of the lift by means of the landing buttons when the car is in motion. Controller interlocks to be fitted on the safety gear and on the brake hand release lever when this is fitted.

Speed. When determining a suitable car speed, the height of the building, distance between stops and quality of service desired must all be considered. The higher the car speed the better the resulting service, but it must be remembered that the cost of a lift increases as the maximum running speed is raised. If a large amount of interfloor traffic is anticipated, the car speed should not exceed about 250 ft. per min., otherwise most of the running time will consist of acceleration and retardation and the motor will not have sufficient time in which to travel for an appreciable distance at its full speed. In buildings of five or six stories, where a fair amount of traffic from the ground to the upper floors is expected, speeds up to 400 ft. per min. are now common. A number of the larger buildings in this country having upwards of about eight stories employ car speeds of up to 600 ft. per min. In America, however, several of the "skyscrapers" have upwards of fifty stories, and speeds of 800 ft. per min. are quite common, whilst the larger of these buildings are equipped with lifts travelling at 1 400 ft. per min. These high speeds are only used for express service to the upper floors.

When installing a lift in an existing building, however, other factors such as the available top and bottom clearances may limit the lift speed.

Size and Capacity of Car. In deciding the car size it is usual to allow 2 $ft.^2$ for each passenger and 3 $ft.^2$ for the attendant. The internal height is generally not less than 7 ft. To calculate the size of the lift machine, the car loading must be known, and in arriving at this the average weight of each passenger is taken as 150 lb., but frequently $1\frac{1}{2}$ cwt. is used as a rough approximation.

Type of Control. When considering the method of control to be adopted, the type of building and of its occupants and the lift capital cost are the determining factors. For intermittent traffic an attendant is not justified, and an automatic form of control should be installed. On the other hand, when the traffic is likely to be fairly regular, better service will be maintained by employing a car attendant and adopting car switch control. If the traffic is intermittent for the greater part of the day, but definite peak periods are expected, such as in the early morning, at mid-day, and in the evening, it is advisable to install a dual form of control. With this control, the car is normally worked automatically by the passengers, but by an attendant and car switch control during the periods of heavy traffic. In certain circumstances, where the extra cost is warranted, automatic collective control is adopted.

Cost. A high grade geared lift with a maximum speed of 300 ft. per min., capacity 15 cwt., manually operated gates, dual control, serving five floors, will cost about £1 000, although makers' prices vary considerably. The occupants of the building, however, may be of sufficient importance to justify providing the best possible grade of service, and then a variable voltage equipment becomes necessary in order to secure the smoothest and most rapid acceleration and retardation at present obtainable. Other desirable features, in some cases, are collective control and power-operated automatic doors and gates. If the provision of these luxuries can be justified, the cost of the lift will rise to something in the neighbourhood of £3 000.

Bank of Lifts. The larger buildings require several lifts to provide satisfactory service, and in these cases the lifts are arranged in a bank, i.e. side by side. A bank of passenger lifts operated by gearless variable voltage control is shown in Fig. 1, and a bank driven by a.c. commutator motors in Fig. 2. In determining the most suitable car speeds, capacities, and number of cars, many variable factors must be taken into account, as there are several combinations of speed, capacity, and number of cars, each of which will give satisfactory service but with varying degrees of efficiency. No definite rules for selection can be given, but the various factors, e.g. round trip time, speed, and capacity, must be considered and the most likely schemes

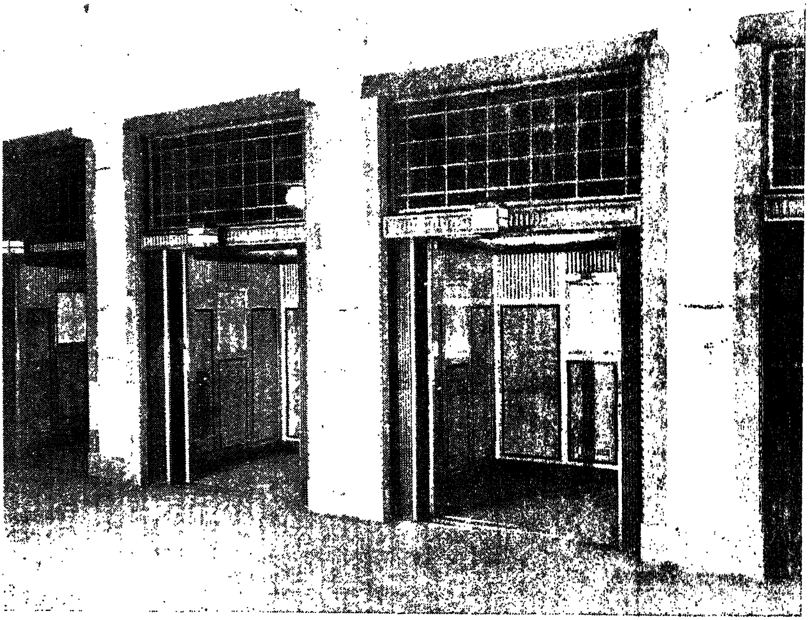


FIG. 1. BANK OF GEARLESS VARIABLE VOLTAGE PASSENGER LIFTS
(*Wm. Wadsworth & Sons*)

worked out, the final decision being largely a matter of judgment.

Whatever combination of speed, capacity, and number of cars is ultimately selected, the installation must be capable of handling the traffic during the peak periods, which are usually in the morning and evening in office buildings. The number of passengers during these peaks therefore becomes the basis of any calculations which may be made.

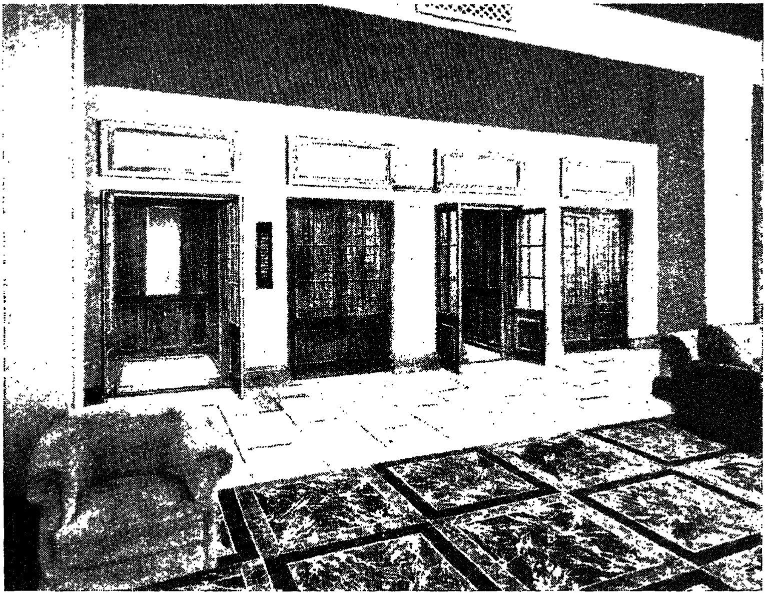


FIG. 2. PASSENGER LIFTS AT GROSVENOR HOUSE
(*Etchells, Congdon & Muir*)

The number of passengers carried during the peak period = No. of passengers carried per journey × No. of journeys made during the peak period.

The number of cars in the bank $= \dfrac{\text{No. of passengers carried.}}{\text{No. of passengers per car.}}$

When determining the quality of service which will be rendered, the round trip time, i.e. the time which elapses between leaving the ground floor and again arriving at that floor after completing a full journey and making the average number of stops, together with the waiting interval between the arrival of cars, must be taken into account. The round trip time is composed of the following varying factors.

(*a*) *Maximum Running Speed of Cars.* This is mainly determined by the height of the building and the distance between the average stops. In this country speeds up to about 600 ft. per min. are employed in the larger buildings of eight stories and upwards.

(*b*) *Rates of Acceleration and Retardation.* These are approximately 3 ft. per sec. per sec., but may be as high as 5 ft. per sec. per sec. when gearless machines and variable voltage equipment are installed.

(*c*) *Average Number of Stops Made per Journey.* An approximation only can be arrived at after closely considering the type of service.

(*d*) *Average Distance between Stops.* This will be covered during acceleration, maximum speed, and retardation periods.

(*e*) *Time Required for Passengers to Enter and Leave the Car.* This time will be influenced by the width of the car and landing doors and their method of operation. The operating time will be shorter with power-operated doors, and with the centre opening type should not be more than about 2 sec.

The round trip times for several different types of installations having varying speeds, types of doors, and lift machines may be calculated by assessing values for the factors mentioned above.

The quality of service given by an installation is measured by the time of the waiting interval together with the time for the car to arrive at an average floor, the latter being a function of the round trip time. Waiting intervals of say, 20, 30, and 40 sec. may be considered, but a passenger should never be expected to wait more than 40 sec. before the arrival of a lift.

Irrespective of the capacity of each car the number of cars $= \frac{\text{Round trip time}}{\text{Waiting interval}}$. Hence with a round trip time of 150 sec. and a waiting interval of 30 sec., the number of cars is 5.

The relative merits of different installations may be compared by paying due regard to all the variables mentioned.

Other factors which influence the final choice are the building space required for the lifts and capital and running costs.

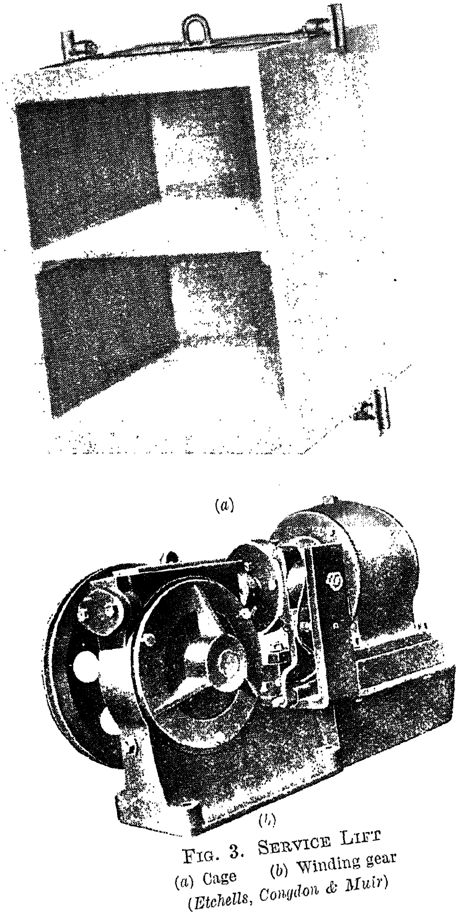


FIG. 3. SERVICE LIFT
(a) Cage (b) Winding gear
(*Etchells, Congdon & Muir*)

GOODS LIFTS

In many buildings it is necessary to install one or more goods lifts, these being designed primarily for the transport of goods but occasionally to carry passengers. The design of a goods lift is similar in principle to that of a passenger lift, the main exceptions being that the car is of rougher construction and the maximum speed rarely exceeds 250 ft. per min. Accurate levelling, however, may be essential to facilitate the loading and unloading of trolleys filled with fragile goods, and in these cases one of the available schemes of corrective levelling is generally incorporated. The service is usually intermittent, and the control is therefore either automatic or semi-automatic.

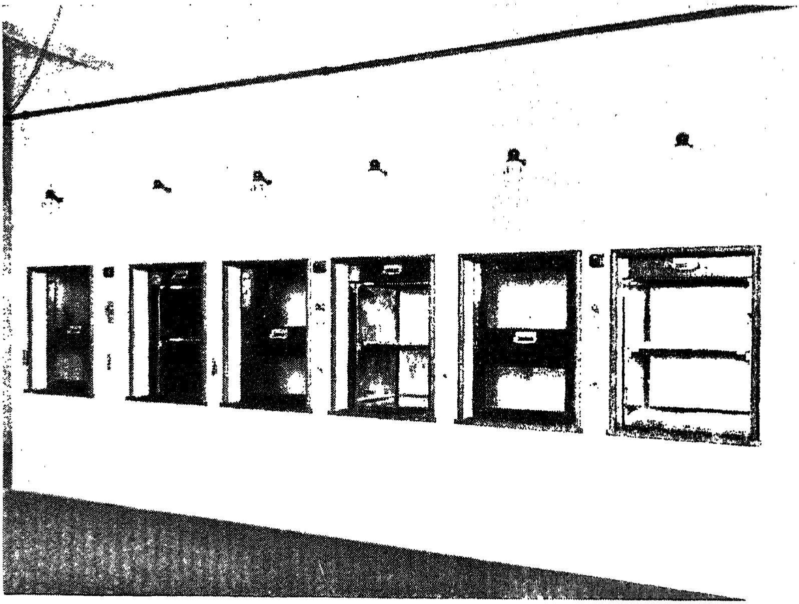


FIG. 4. GROUP OF SERVICE LIFTS
(*Marryat & Scott*)

SERVICE LIFTS

A service lift is one which is designed and constructed so that it is possible for goods only to be carried, and the factor of human safety does not therefore enter so largely into the design of these lifts. Fig. 3 shows a typical service lift car and winding machine. The type is chiefly used in hotels and restaurants for service from the kitchens to the dining-rooms, in banks for the transport of bullion, and in libraries for transport of books.

The general principles governing the design are similar to those for a goods lift, but the machine and car are much smaller in size and safety gear is generally omitted. The speed of travel is invariably between 50 and 150 ft. per min., whilst the control is either automatic or semi-automatic. Fig. 4 shows a group of service lifts with cars lined with monel metal and entrances protected by bi-parting rise and fall shutters. A service lift built into a bookcase is shown in Fig. 5.

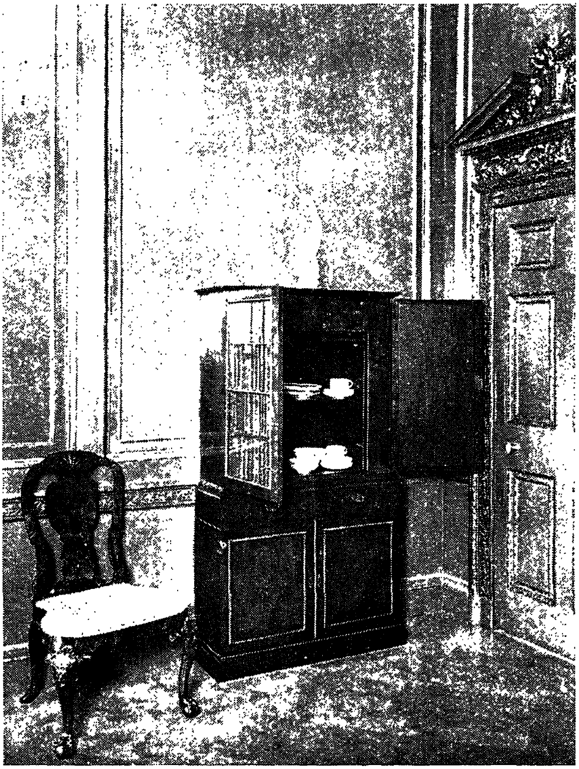


FIG. 5. SERVICE LIFT CONCEALED IN BOOKCASE
(Marryat & Scott)

The table on pages 12 and 13 gives details of typical modern British lift installations built by some of the leading manufacturers.

DETAILS OF MODERN LIFT INSTALLATIONS

Type of Lift	Type of Building		Max. Load (lb.)	Max. Speed (ft. per min.)	Total Travel ft. in.	No. of Floors	Motor and Drive	Control System, etc.
PASSENGER	OFFICES	†	1 950	500	51 6	7	Gearless traction—variable voltage	Car switch with interconnected annunciators and electric power-operated doors—low voltage control—two lifts
		‡	2 350	450	65 0	6	Gearless traction—variable voltage	Car switch (one lift)—automatic (one lift)
		†	1 680	400	59 3	6	Gearless traction—variable voltage	Full button collective—low voltage control
		*	2 000	400	124 0	10	Gearless traction—variable voltage	Car switch
		†	1 344	350	78 0	8	Geared traction—variable voltage	Car switch—low voltage control
		†	2 240	300	71 0	6	Gearless traction—variable voltage	Dual—low voltage control
		‡	3 360	300	117 0	9	Gearless traction—variable voltage	Car switch—electric power-operated gates
		*	2 000	300	51 0	4	Geared traction—variable voltage	Duplex collective
		‡	1 340	300/50	62 0	6	Geared traction—tandem motor	Car switch
		‡	3 360	200/34	47 6	5	Geared traction—tandem motor	Car switch
	FLATS	†	1 400	250	95 9	11	Geared traction—slip ring variable voltage	Automatic when travelling up and collective when travelling down—low voltage control
		*	1 200	200	56 9	7	Geared traction	Automatic—down collective
		†	900	120	47 6	6	Geared traction—squirrel-cage two-speed pole change motor	Automatic—low voltage control
		†	1 200	120	99 0	12	Geared traction—squirrel-cage single-speed motor	Collective—low voltage control
		†	900	100	51 6	6	Geared traction—slip-ring single-speed motor	Automatic—low voltage control
	BANKS	*	3 360	500	99 6	9	Gearless traction—variable voltage	Duplex collective
		*	1 200	250	88 0	8	Geared traction	Automatic collective
	HOTELS	*	3 000	450	108 3	10	Gearless traction—variable voltage	Car switch—signal control
		*	1 200	200	64 6	6	Geared traction	Dual control
	STORES	†	2 500	350	92 0	8	Gearless traction—variable voltage	Car switch with interconnected signals—low voltage control—three lifts
		‡	4 000	350	101 6	8	Gearless traction—variable voltage	Car switch—pneumatic gate gear—ten lifts
		‡	2 500	300	72 0	6	Gearless traction—variable voltage	Car switch—pneumatic gate gear—ten lifts

	FACTORIES	†	1 200	450	205 0	10	Gearless traction—variable voltage	Collective—low voltage control
		*	1 350	300	73 0	6	Geared traction	Automatic
	TUBE RAILWAY STATION	*	4 800	600	85 0	2	Gearless traction—variable voltage	Special automatic
	MERSEY RAILWAY	‡	8 400	400	76 7	2	Gearless traction—variable voltage	Automatic—pneumatic gate gear
	MERSEY TUNNEL	‡	1 340	330/45	80 9	2	Geared traction—a.c. comm. motor	Automatic
	TELEPHONE EXCHANGE	‡	1 680	300	74 0	6	Geared traction—variable voltage	Car switch
	FULHAM POWER STN.	‡	1 000	200/16	115 0	7	Geared traction—a.c. comm. motor	Automatic
BED	HOSPITAL	†	1 120	200	61 0	7	Geared traction—d.c. three-speed motor	Automatic up, collective down—low voltage control
	CLUB	†	1 120	200	77 1	9	Geared traction—tandem motor	Automatic up, collective down—low voltage control
GOODS	OFFICES	*	4 480	225	124 3	10	Geared traction—micro drive	Car switch—corrective levelling
		†	2 240	200	98 5	7	Geared traction—variable voltage	Collective—low voltage control
	FACTORIES	‡	3 360	215/48	96 0	8	Geared traction—tandem motor	Car switch
		†	3 360	200	75 6	7	Geared traction—slip-ring variable voltage	Car switch—low voltage control
		†	2 240	200	53 8	5	Geared traction—squirrel-cage two-speed pole change motor	Special automatic—short floors served at low speed and main floors at high speed
		‡	6 700	100/17	36 0	4	Geared traction—tandem motor	Automatic
		†	6 720	100	70 0	7	Geared traction—d.c. three-speed motor	Automatic with corrective levelling when gates open
	G.P.O. SORTING OFFICE	‡	4 480	200/25	68 0	6	Geared traction—a.c. comm. motor	Dual—corrective levelling
SERVICE	OFFICES	*	200	140	8 0	2	Geared traction	Semi automatic
	BANK	*	800	60	9 0	2	Geared traction	Automatic
	HOTEL	*	150	150	79 3	4	Geared traction	Automatic

*By courtesy of Messrs. Waygood, Otis.
‡ ,, ,, ,, Wm. Wadsworth & Son.
† ,, ,, Express Lift Co.

CHAPTER II

ACCOMMODATION

Well. In most buildings the lift well is placed in the main staircase, but, whilst this position has some advantages, lift engineers nowadays frequently avoid the stairs when designing the well and, in fact, in America some building authorities prohibit the erection of the well in the stairway, the latter being regarded solely as a means of exit during emergency. The advantages of placing the well in a separate portion of the building are that there is not the same tendency for dirt to accumulate, and no special methods of guarding and screening are necessary. A typical guarded stairway well is shown in Fig. 6. Furthermore, most stairway wells are unsightly, and so the architect who avoids using them for his lifts is better able to contrive a more pleasing appearance for his lift entrances. An example of a totally enclosed well with an effective entrance is shown in Fig. 7. The main point for consideration is that the lift should afford a quick and easy means of access to an exit from the upper floors.

The area of the well is governed by the size and number of the cars, and by the disposition of the car and landing entrances; these entrances also determine the necessary clearances for the car and counterweight. Various arrangements of openings met with in practice, with suitable clearances for car and counterweight, are shown in Fig. 8, although the clearances will depend upon the type and method of fixing of the guides. Sufficient pit depth must be allowed to enable the car to come to rest without excessive buffer shock after operating the final limit switch in the event of the terminal limit switch failing to operate. The depth required depends upon the maximum car speed and the type of buffer employed. The minimum overhead clearance which should be given is also a function of the maximum car speed. These clearances are given in Chapter XII. Provision must be made in the pit bottom for the accommodation of buffers, usually two for the car and two for the counterweight, and for the fixing of the guide ends. Counterweight buffers, whilst not installed on all lifts, are invariably provided when the well does not extend to the basement. In these circumstances a special framing is erected for the buffers, and this must be capable of supporting the weights of the car and

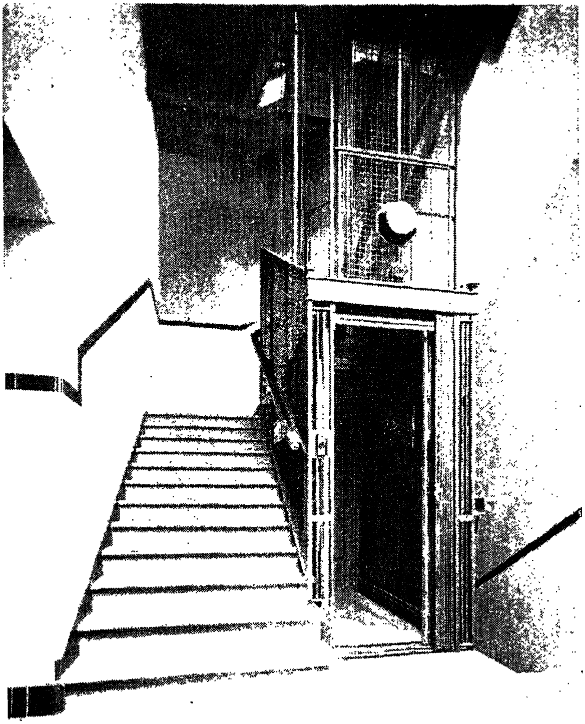


FIG. 6. STAIRCASE LIFT
(Marryat & Scott)

counterweight together with a possible impact strain. The lift machine is generally either in the basement or at the top of the well, but in both cases a suitable structure is required at the top of the well. In the former case the top joists must be capable of supporting the diverting pulleys and their resultant loads, whilst in the latter case the top structure is subjected to the weights of the machine, car, counterweight, and control gear. With the basement position, the machine should never be immediately under the well, and it is therefore necessary to provide joists for supporting the bottom pulleys which lead the ropes into the well. It is frequently possible to fix the main supporting joists to the building framework, but in some cases this is impracticable and it then becomes necessary to erect an independent steel structure from the basement and so relieve the building fabric of all lift loads. The well is usually of brick construction faced either with plaster or some form of ornamental glazed brick, except when a steel structure has to be erected.

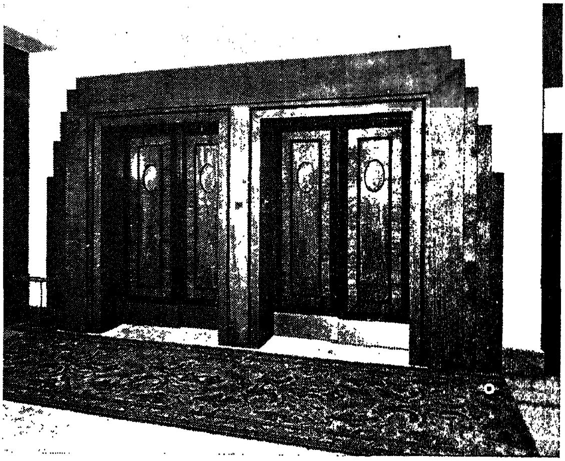
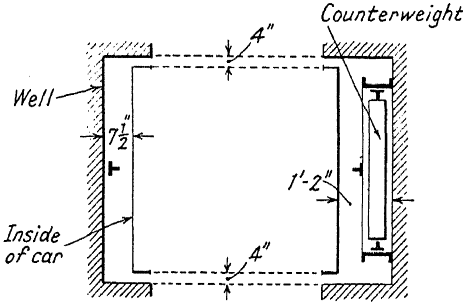


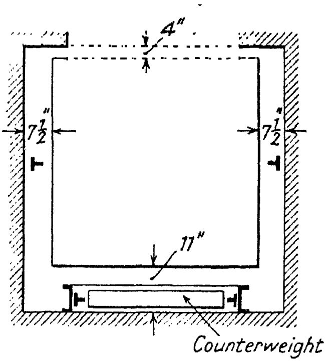
FIG. 7. TWO LIFT ENTRANCES
(*Marryat & Scott*)

Well openings all on one side should be arranged if possible, as this permits of a simple guide arrangement and cheaper car construction. Exits on opposite sides can be arranged without difficulty, but openings on adjacent sides involve guiding the car at its corners.

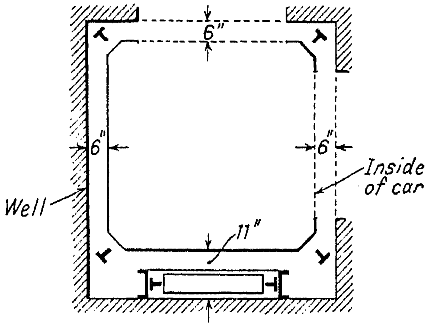
Guarding. A counterweight guard of wire mesh is fixed in the well at the position where the car and counterweight pass each other in order to eliminate the possibility of injury to the maintenance engineer when travelling on top of the car. External counterweight guards of mesh not greater than $1\frac{1}{4}$ in. are fitted to stairway wells when these are not completely enclosed, as a protection for persons using the staircase. In addition, with an open type well, if the clearance between the enclosure and any moving part of the lift is less than 2 in., the enclosure openings should be further protected by square mesh netting not greater than $\frac{1}{2}$ in. mesh and not smaller than 20 S.W.G. wire. A counterweight guard is often fitted in the pit to eliminate the possibility of injury to anyone working there.



(a) Two Opposite Openings



(b) One Opening



(c) Two Adjacent Openings

FIG. 8. CAR CLEARANCES

Machine Room. The overhead location of the lift machine shows a saving in first cost and has several engineering advantages over the basement or any intermediate position. The machine room should therefore, whenever possible, be situated directl over the well and should have sufficient windows to afford od natural lighting and ventilation. The former is necessa for efficient maintenance, and adequate artificial lighting supplemented by hand lamp points should be provided

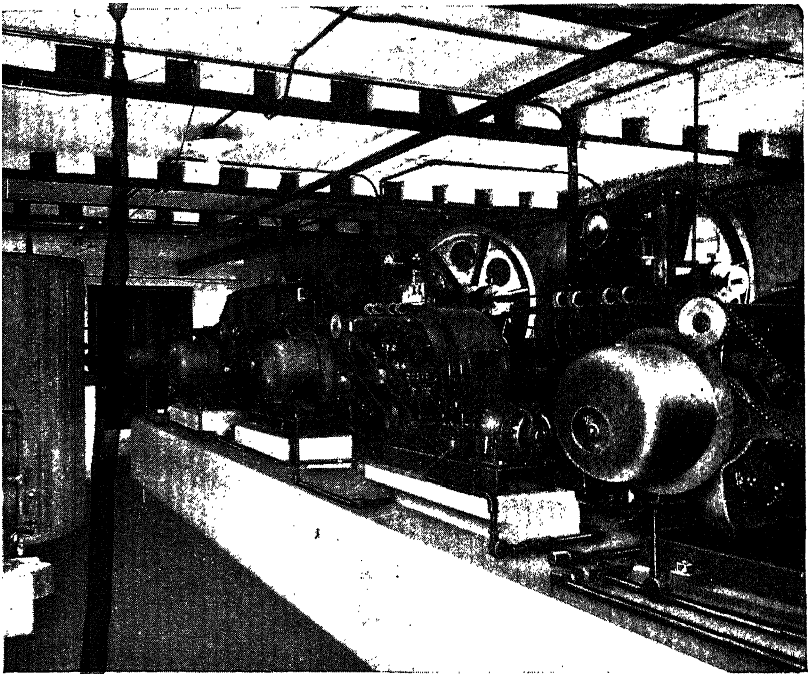


FIG. 9. LIFT MOTOR ROOM AT GROSVENOR HOUSE
(*Etchells, Congdon & Muir*)

for carrying out any work necessary during hours of darkness. Efficient ventilation is provided mainly to reduce the temperature and resistance of the motor windings, and thereby increase the electrical efficiency of the plant. Fig. 9 shows the machine room for the lifts in Fig. 2, whilst an overhead machine room (unfinished) for a bank of seven gearless machines is shown in Fig. 10. In large machine rooms where a number of lift machines are installed it is sometimes the practice to install a Plenum ventilating plant. The incoming air is drawn through oil filters and thence by ductwork to the generators and motors, a separate exhaust system being provided. The clear room height should not be less than 7 ft. to comply with the Home Office Regulations. The entrance door should preferably open outwards, and when it is essential to locate the machine below, access doors must be provided at the top of the well to enable the necessary periodical attention to be given to the overhead pulleys.

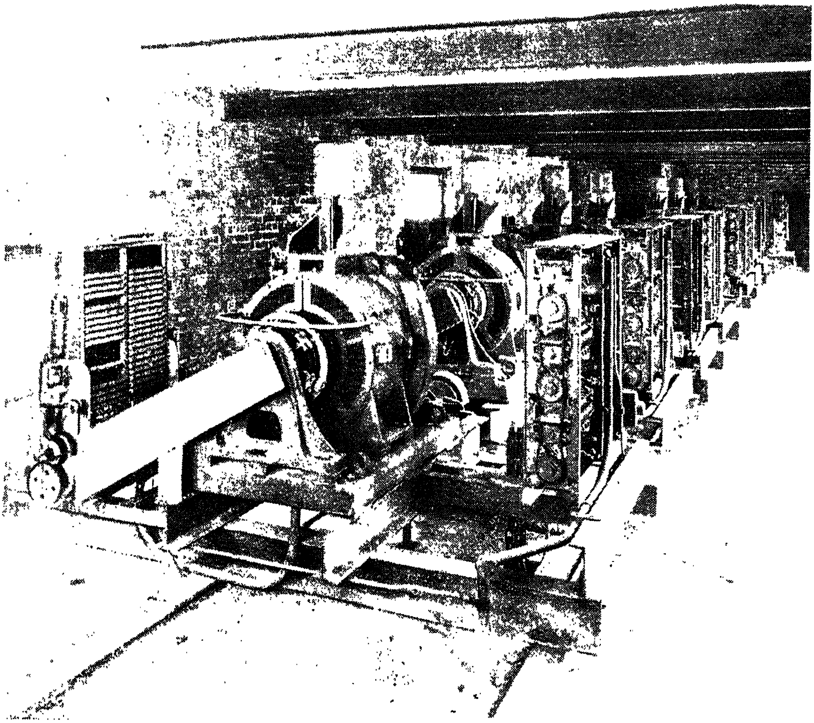


FIG. 10. MOTOR ROOM
Showing seven "Gearless" lift motors. (At the time the photograph was taken the installation was in an unfinished state)
(*Wm. Wadsworth & Sons*)

The area of the room depends upon the lay-out and type of the lift equipment, the size being governed by the car capacity and speed. Ample space must be provided to facilitate maintenance, and in the lay-out care must be taken to ensure that the controller position conforms to the Home Office Regulations, which demand that there should be a clear width, measured from the bare conductors, of not less than 3 ft. on all sides. When the controller is fixed near a wall the 3 ft. clearance must be provided between the controller and the wall, unless the connexions and all parts requiring attention when the controller is working, are placed on the front of the panel. The areas of well-designed machine rooms for various capacity single lifts will, in practice, be found to be not less than those quoted below for ordinary geared lifts. Larger rooms will be required if variable voltage equipment is provided or if accommodation is required for any air-compressing plant for power-operated doors.

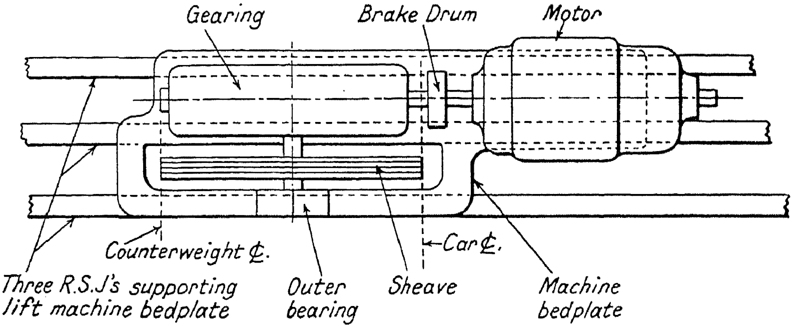
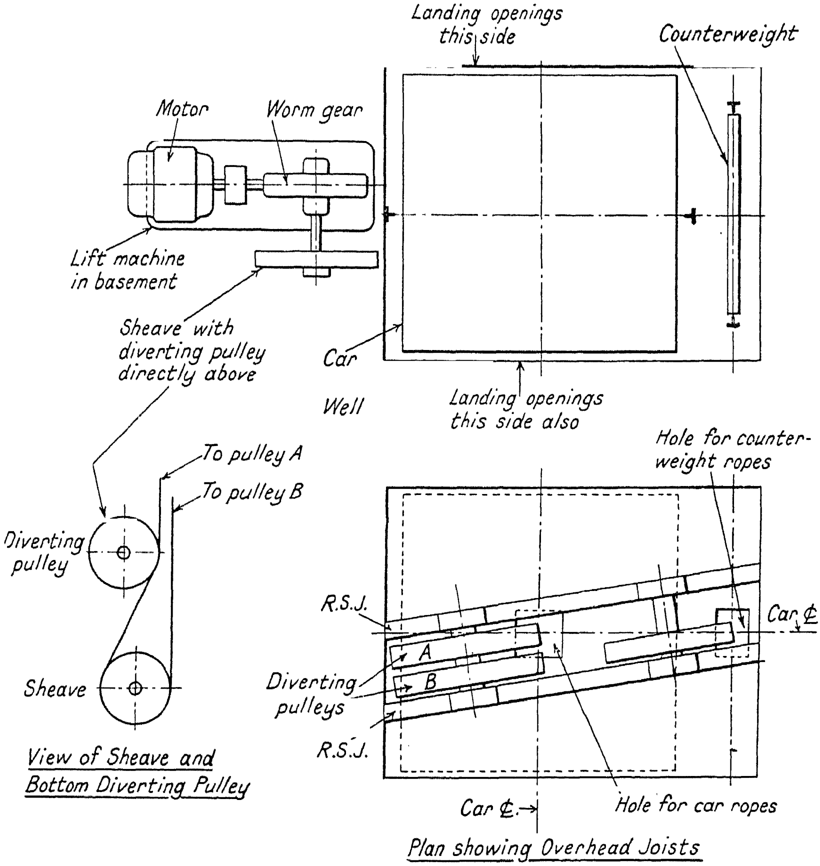


FIG. 11. R.S.J.'s SUPPORTING OVERHEAD LIFT MACHINE

Car Capacity (cwt.)	Size (ft.^{2})	Car Capacity (cwt.)	Size (ft.^{2})
10	120	25	170
15	140	30	180
20	150	35	190
		40	200

Substantial rolled steel joists will be required in the machine room floor to carry the lift loads. If the machine is above the well, the total load to be supported will be the sum of the weights of the machine, car, load, counterweight, controller,



View of Sheave and Bottom Diverting Pulley

Plan showing Overhead Joists

Fig. 12. Details of Traction Drive with Machine Below

and sundry other small gear. The greater part of this load is "live," and the supporting joists must therefore be designed to carry double the "dead" load, and, further, as the load is unequally distributed, comparatively large section joists are necessary. The actual arrangement of these joists depends upon the lay-out of the machine, three typical supporting joists being shown in Fig. 11. With the basement location, overhead joists will be required to support a total load equal to twice the sum of the weights of car, load, and counterweight, and as this is a "live" load, the equivalent "dead" load will be twice this figure. Overhead joist arrangements for basement machines are shown in Figs. 12 and 13. Lifting joists must also be fixed in the motor room to enable the machine to be placed in position and to allow of ready removal of any part for repair or renewal.

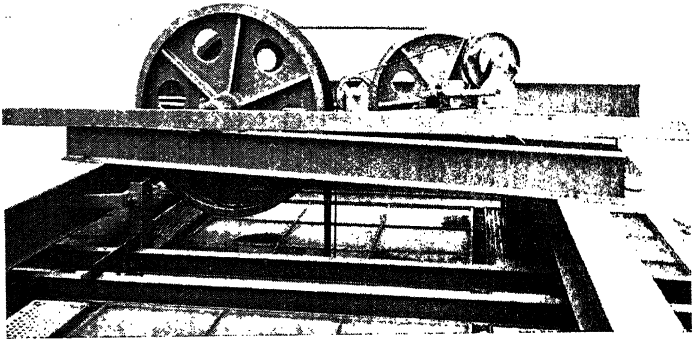


FIG. 13. OVERHEAD JOISTS AND PULLEYS
(*Marryat & Scott*)

Noise. In some buildings, notably hospitals, silence is of paramount importance, and various measures must be adopted if it is desired to reduce the lift noise to the lowest possible level. This is generally a difficult problem, as with modern steel-framed buildings noise is readily transmitted to rooms which may be at a considerable distance from the motor room. When silence is important, it is usually better to accommodate the lift machine in the basement.

In dealing with the problem of noise it is necessary first to reduce the noise generated in the motor room itself to a minimum. A reasonably silent motor may be obtained by carefully selecting the type, paying due regard to its design, and by employing plain bearings. Motors fitted with commutators should have the micas undercut and the brushes carefully bedded. Motor hum may be considerably reduced by using a motor frame size larger than that required to give the necessary horse-power output and thus working the magnetic circuit below its saturation point. Brake noises will be diminished if the brake is immersed in oil, and often by incorporating torque

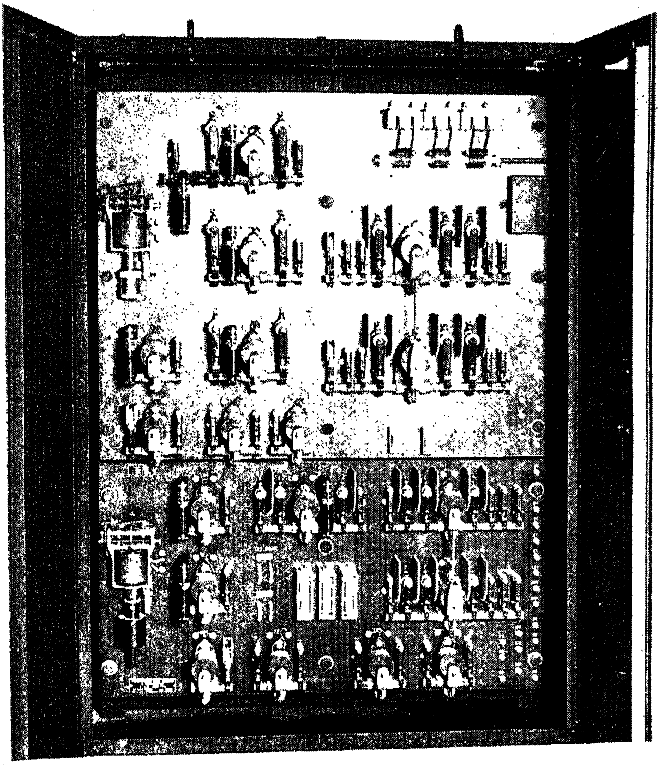


FIG. 14. ENCLOSED CONTROLLER
(Doors open)
(*Marryat & Scott*)

motor brakes instead of the usual type, whilst hum due to a.c. brakes can be reduced by using shaded poles, i.e. inserting copper loops in the face of each magnet core. The gearing should be silent in operation if the gear teeth are accurately cut, and the same applies to gearing on floor selectors. Considerable noise emanates from the controller switches during the starting, acceleration and stopping periods, and only by giving attention to design or totally enclosing the controller is it possible to diminish these noises to a negligible amount. A totally enclosed controller constructed so that no live metal is exposed is shown in Fig. 14. When the doors are open as shown in Fig. 14 all "live" parts are "dead."

Having eliminated the noises generated in the machine room as much as possible, the next step is to prevent that which remains from being transmitted to other parts of the building. Direct transmission of noise by the air can be reduced by lining the machine room walls with some sound insulating material such as Cabot's quilting or "Absorbit." Noise transmitted via the well may be greatly diminished by providing a free circulation of air between the machine room floor and the top of the well. This entails building a false floor about 3 ft. below the machine room floor and ensuring a free circulation of air through this space. Vibration transmitted by the building structure can be reduced by inserting slabs of compressed cork or similar material between the concrete bed on which the machine baseplate rests, and the supporting joists. As an additional precaution the ends of the joists may be surrounded by insulating material in boxes before bedding in the walls.

Other lift noises are due to the motion of the car and counterweight in the well, and to the operation of gates and doors. The former may be diminished by fitting a retiring lock release cam to the car and thus preventing the cam hitting the gate lock striker arm when passing landings. The noise due to the motion of the car and counterweight on their guides may be prevented from being transmitted to adjacent rooms by inserting a felt sleeve around each guide fixing bolt. A more complete but also more expensive method of effecting this is to construct double well walls, the inner wall carrying the guides, the intervening space forming a sound absorbing chamber.

Gate noises may be reduced by the insertion of rubber buffers between the pickets, rubber bumpers at the extremes of travel, and by fitting hardwood bottom gate tracks instead of steel tracks.

CHAPTER III

TYPES OF DRIVES

Two types of drives are employed for lift work, namely, the *traction* or *sheave* drive, and the *drum* drive.

TRACTION DRIVE

In this case one set of ropes is used, the ropes passing from the car around a cast-iron grooved sheave and thence to the counterweight. Friction between the ropes and the sheave grooves therefore supplies the force necessary to raise or lower the car. The sheave is secured to a turned mild steel shaft by two sunk keys at right angles to each other. Alternatively, keys may be eliminated by bolting the sheave rim to a gear and sheave centre. This centre is a casting with two flanges, one of which carries the sheave, the other carrying the worm-wheel rim, the shaft being pressed into the bore of the centre. The outer end of the driving shaft is carried in a pedestal bearing fitted with readily renewable bearings of gunmetal or white metal, preferably of the split pattern, in order to compensate for wear. In those cases in which no outer shaft bearing is employed, the outer edge of the sheave is fitted with an extended flange to minimize the danger of the ropes leaving the sheave. A lift machine with no outer bearing is shown in Fig. 15.

The main advantage of the traction drive is that if either the car or counterweight comes into contact with the buffers, the drive ceases and there is no danger of the car being wound into the overhead structure, as would be possible with a drum machine. Other advantages of this method are cheapness, simplicity, and the fact that standard equipment may be used irrespective of the height of travel. A view of a typical traction machine is shown in Fig. 16.

Sheaves. Sheave is the name given to a pulley to which power is applied, and is that part of the lift machine transmitting driving power to the lift ropes. The sheave is of disc construction, i.e. without spokes, and to ensure a long life for the ropes the sheave diameter should be as large as practicable, the minimum depending upon the rope diameter, material and construction and the maximum car speed. A larger diameter

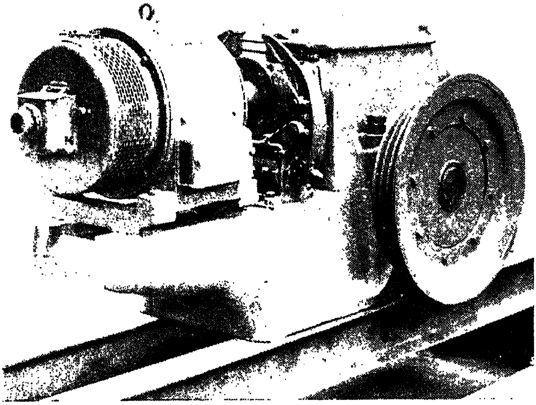


FIG. 15. LIFT MACHINE WITH NO OUTER SHEAVE BEARING
(*Wm. Wadsworth & Sons*)

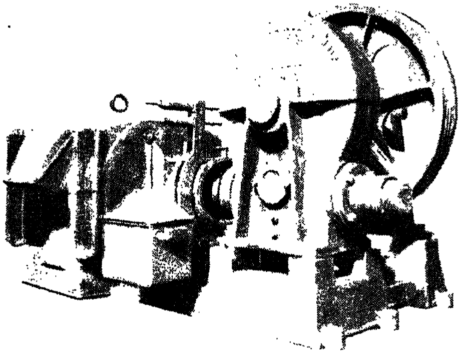


FIG. 16. TYPICAL UNDER-TYPE GEARED WINDING MACHINE
(*Etchells, Congdon & Muir*)

sheave should be employed for Seale or Warrington ropes than for ropes of uniform construction, whilst ropes of low tensile strength and consequently high ductility may be used with sheaves of smaller diameter than high tensile strength ropes would require. Although the specified figures for the ratios of sheave to rope diameters vary with different authorities, a sheave diameter of not less than 50 rope diameters is a good value for practically all types of ropes if the car speed does not exceed 300 ft. per min. The following table from B.S.S. 329, *Round Strand Steel Wire Ropes for Lifts and Hoists*, gives the minimum ratios of sheave diameter to rope diameter for various types of ropes used on cars running at speeds below 250 ft. per min.

Tensile Breaking Strength (tons per in.^{2})	Minimum Sheave or Drum Diameter (D = rope dia.)			
	$\frac{6}{12}$ and fibre	$\frac{6}{19}$	$\frac{6}{19}$ Seale	$\frac{6}{24}$
60–100	33D	33D	40D	27D
100–120	40D	40D	50D	32D

For each increase in speed of 100 ft. per min., 7½ per cent should be added to the drum or sheave diameter. The importance of specifying a large sheave diameter is clearly shown in *Fig. 17, which is a graph showing the relation between number of bends before failure and increasing sheave diameters for different values of the ratio $\frac{\text{Rope Strength}}{\text{Working Tension}}$. The graph is plotted from results obtained during a test taken on a sample of $\frac{6}{19}$ ordinary lay rope. It also shows that the rope performance is improved if this ratio is large.

The type of sheave groove usually employed is vee-shaped, having an included angle of from 30° to 45°; the angle recommended in B.S.S. 329, *Round Strand Steel Wire Ropes for Lifts and Hoists*, is 42°. With a small groove angle the traction is large, but it is necessary to use hard ropes so as to minimize rope wear. Details of a typical vee-grooved traction sheave are shown in Fig. 18. On modern high speed lifts a U-groove, similar to that used on a drum or pulley, is frequently employed, but the traction is so low with this groove as to necessitate the use of the double-wrap method of roping. The U-groove, however, has the advantages of longer rope life and a greater degree of silence, the latter being particularly noticeable at

---

* "Wire Ropes," paper by W. A. Scoble read before the Junior Institution of Engineers.

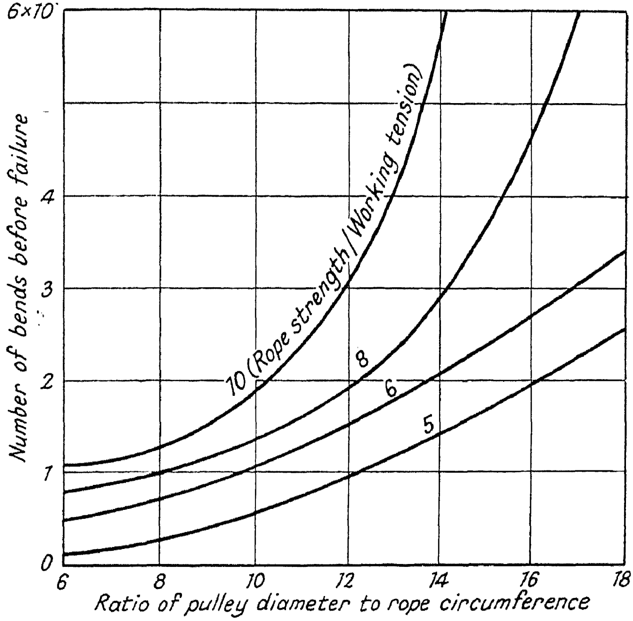


FIG. 17. GRAPH SHOWING RELATION BETWEEN NUMBER OF BENDS BEFORE FAILURE AND INCREASING PULLEY DIAMETER
(*Junior Institution of Engineers Journal*)

the higher car speeds of 600 ft. per min. and over, employed in America. Other types of sheave grooves sometimes used (Fig. 19) are a modified form of vee-groove and an undercut groove, these being compromises between the vee- and U-types.

It will be appreciated that all traction drives rely for their effectiveness upon friction between the ropes and the sheave grooves, the tractive force available depending upon the coefficient of friction between the ropes and the sheave, the groove angle, and the amount of rope wrap. These three factors govern the ratio which can exist between the rope tensions on the two sides of the sheave before slipping occurs.

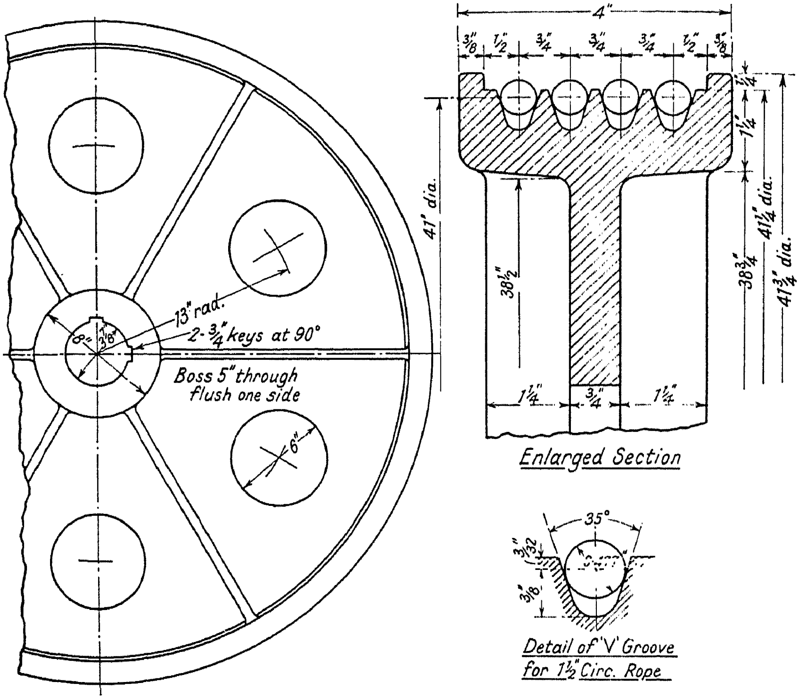


FIG. 18. VEE-GROOVED SHEAVE FOR $1\frac{3}{4}$ IN. CIRCUMFERENCE ROPES AND 41 IN. ROPE CENTRE DIAMETER
(*R. J. Shaw & Co.*)

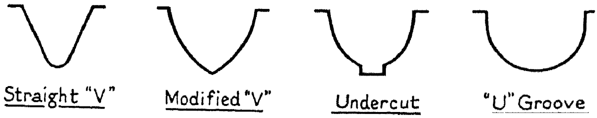


FIG. 19. TYPES OF GROOVES

This maximum ratio between the rope tensions on the "tight" and "slack" sides of the sheave may be calculated as follows for both single-wrap and double-wrap drives.

SINGLE-WRAP DRIVE. In Fig. 20 let

T_1 = tension on tight side of rope.
T_2 slack
θ = angle subtended by that portion of the rope in contact with the sheave.
bc = indefinitely small portion of BC.
$d\theta$ = angle subtended by bc
T = tension in rope at c.
$T + dT$ = ,, ,, ,, b.
S = resultant pressure of the sheave on portion bc of rope.
μ = coefficient of friction between rope and sheave.

Then at the moment when slipping occurs

$$(T + dT) - T = \mu S.$$

but $S = T \, . \, d\theta \ldots$ (Triangle of forces, Fig. 20 (b).)

$$\therefore \quad dT = \mu T d\theta.$$

$$\therefore \quad dT/T = \mu d\theta.$$

$$\therefore \quad \int_{T_2}^{T_1} \frac{dT}{T} = \mu \int_0^\theta d\theta.$$

$$\therefore \quad \log_e (T_1/T_2) = \mu\theta, \text{ or } T_1/T_2 = e^{\mu\theta} \quad \ldots \ldots \ldots \quad (1)$$

Since, however, the rope lies in a vee-groove as shown in Fig. 20 (c), the effect is to increase the resistance to slipping due to the wedging action between the two surfaces. The resistance to slipping in element bc is $2\mu R$.

But from Fig. 20 (d), $S = 2R \sin \alpha$, where 2α is the angle of the groove.

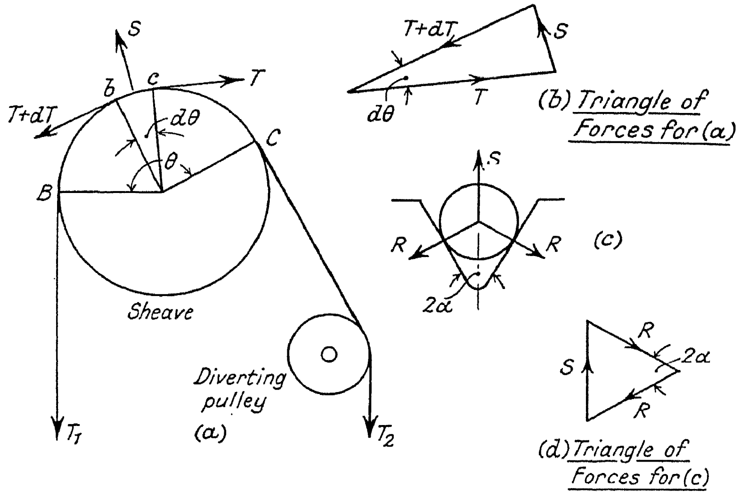
$$\therefore \quad 2R = S \operatorname{cosec} \alpha.$$

Hence the resistance to slipping in bc is $\mu S \operatorname{cosec} \alpha$.

In equation (1) above, in which the effect of the vee-groove has been neglected, the resistance to slipping in bc was μS. For this equation to be applicable to a rope in a vee-groove it is, therefore, necessary to substitute $\mu \operatorname{cosec} \alpha$ for μ and the equation then becomes

$$T_1/T_2 = e^{\mu\theta \operatorname{cosec} \alpha} \quad \ldots \ldots \ldots \ldots \ldots \quad (2)$$

It will be observed from equation (2) that when an idle pulley is employed and the angle θ is thereby reduced, the traction is consequently less. To be rigidly accurate, the area of contact should be considered as μ is a function of the unit pressure.



(b) Triangle of Forces for (a)

(c)

(d) Triangle of Forces for (c)

FIG. 20. ROPE AND SHEAVE FORCES IN SINGLE-WRAP DRIVE

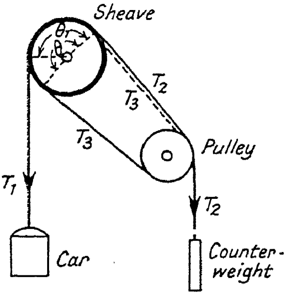


FIG. 21. DOUBLE-WRAP DRIVE

DOUBLE-WRAP DRIVE (see Chapter IV). Using symbols as shown in Fig. 21

$$T_1/T_3 = e^{\mu\theta_1 \operatorname{cosec} \alpha}$$

and $$T_3/T_2 = e^{\mu\theta \operatorname{cosec} \alpha}.$$

$$\therefore T_1/T_2 = (T_1/T_3) \times (T_3/T_2)$$

$$= e^{\mu\theta_1 \operatorname{cosec} \alpha} \times e^{\mu\theta \operatorname{cosec} \alpha}.$$

$$\therefore T_1/T_2 = e^{\mu \operatorname{cosec} \alpha\, (\theta + \theta_1)}.$$

The traction is therefore increased by employing the double-wrap drive.

Coefficient of Friction. From the above equations it is observed that the maximum ratio of rope tensions is a function of the coefficient of friction between the ropes and sheave. The minimum value of the coefficient of friction necessary to drive a lift car in any particular installation may be calculated as follows.

Assume that the weights of the car and load are 3 000 lb. and 2 000 lb. respectively, and that the maximum speed of travel is 400 ft. per min.

$$\text{Let counterweight} = \text{Car} + 50\% \text{ load}$$
$$= 4\,000 \text{ lb.}$$

If the car reaches its maximum speed in 2 sec., then the average acceleration is 400/120 = 3·3 ft. per. sec. per sec. The maximum rate of acceleration may be taken as 6·6 ft. per sec. per sec.

After acceleration is completed, $T_1/T_2 = 5\,000/4\,000$.

During the period of maximum acceleration when the tendency to slip is greatest, $\dfrac{T_1}{T_2} = \dfrac{\left(5\,000 + \dfrac{5\,000 \times 6{\cdot}6}{32{\cdot}2}\right)}{4\,000 - \dfrac{4\,000 \times 6{\cdot}6}{32{\cdot}2}} = 1{\cdot}9.$

From above $\quad T_1/T_2 = e^{\mu\theta \operatorname{cosec} \alpha}.$

If $\theta = 180°$ and $2\alpha = 40°$;

then $\qquad e^{\mu\pi \operatorname{cosec} 20°} = 1{\cdot}9.$

$\therefore \qquad \mu = (\log_e 1{\cdot}9)/\pi \operatorname{cosec} 20° = 0{\cdot}07.$

For a steel cable on a cast-iron sheave the value of μ varies from approximately 0·15 to 0·40 as the surface pressure increases from 100 lb. per in.^{2} to 600 lb. per in.^{2} These figures are for dry surfaces, but the value of μ may possibly be as low as 0·06 if the cables are greasy. Hence the importance of ensuring that the amount of lubricant used is kept to a minimum.

Diverting Pulleys. These are idle pulleys used to change the direction of the ropes. With both drum and traction machines it is frequently necessary to employ pulleys to divert the ropes from the sheave or drum to the well. These pulleys are of similar construction to the sheaves, but the grooves are arcs of circles of depth equal to one-third of the rope diameter and of radius slightly larger than that of the rope. The following table from B.S.S. 329, *Round Strand Steel Wire Ropes for Lifts and Hoists,* gives the relationship between the rope radius and the pulley groove radius for various sizes of lift ropes.

Circumference of Rope (in.)	Groove Radius (in.)
2 and under	Rope radius + $\frac{1}{32}$
$2\frac{1}{8}$–$2\frac{3}{4}$	,, ,, + $\frac{3}{64}$
3 –$3\frac{1}{2}$	,, ,, + $\frac{1}{16}$

The pulley diameter is determined in a similar manner to that described for sheave diameters, and a fact which must be borne in mind is that if the rope is bent to the curvature of the pulley, then a small angle of contact has the same effect on the rope as a large angle. It is, therefore, incorrect to assume that if the angle of contact is small a smaller pulley may be employed.

For ordinary conditions the pulleys are bushed with gunmetal and run on fixed steel shafts as shown in Fig. 22, but for high speeds and heavy loads it is usual to key the pulleys to their shafts, the latter running in bushed journal bearings fitted with lubricators.

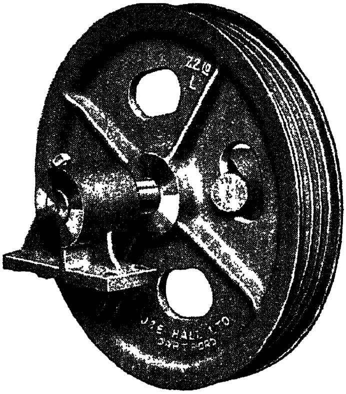


FIG. 22. DIVERTING PULLEY
(*J. & E. Hall, Ltd.*)

DRUM DRIVE

In a drum drive, one end of the car ropes and one end of the counterweight ropes are securely fastened by clamps on the inside of a cast-iron drum, the other ends being fastened to the car and counterweight respectively. One set of ropes is wrapped clockwise around the drum and the other set anti-clockwise, hence when one set is unwrapping the other is being wrapped on the drum. There should be not less than one complete turn of the ropes on the drum when the car or counterweight has reached the extreme limit of its travel and clearance. As the car travels, the ropes move along the drum in spiral grooves cut on its periphery, the grooves being similar to those described for pulleys. The pitch of the groove should be such that there is a clearance of not less than $\frac{1}{16}$ in. between parts of the rope when coiled on the drum. The drum diameter should be as large as practicable in order to obtain a satisfactory rope life, the minimum diameter being determined in a similar manner to that described for sheave diameters.

The disadvantage of the drum drive is that as the height of travel increases, the drum becomes unwieldy, and it is therefore seldom used for rises of more than 100 ft. Because of the many advantages of the traction method, the drum is now almost obsolescent.

CHAPTER IV

ROPING SYSTEMS AND ROPES

METHODS OF ROPING

Several different roping schemes are employed to transmit power from the winding machine to the car. The actual method adopted depends upon local conditions; the situation of the winding machine, and the speed and loading of the car. It is, however, important that particular care should be given to the selection of the roping system, as upon this depends, to a large extent, the life which will be obtained from the lifting ropes. The roping should be as simple as possible and employ the minimum number of pulleys.

The lift machine is usually situated either near the top of the well or as near to the bottom of the well as practicable, but the location which permits of the best and cheapest roping scheme is immediately above the well. A further advantage of the top of the well position is that the loads on the overhead structure are usually smaller than with the machine in the basement, the overhead loads for the two positions being as follows—

(*a*) *Machine Overhead.*

Load = Lift machine + Control gear + Car + Car Load + Counterweight.

(*b*) *Machine Below.*

Load = 2 (Car + Car Load + Counterweight).

The loadings in the two cases are shown in Fig. 23. Hence, in the event of the lift machine (motor, brake, and gearing) together with the control gear weighing more than the combined weights of the car, load, and counterweight, the overhead beams will be subjected to smaller loads with the basement location than if the machine is overhead. For lifts working in hospitals and other buildings where silence is of paramount importance, it is usually advisable to install the machine in the basement. The effective silencing of an overhead installation involves considerable additional cost in providing a specially built insulated motor room. An intermediate floor is sometimes utilized for the winding machine when it is not permissible to install in the top or bottom positions.

Traction Drives. The traction drive shown in Fig. 24 (*a*) is the simplest of all roping schemes and is employed wherever possible. It is sometimes called the *half-wrap* or *single-wrap, one-to-one* system, because the ropes wrap the traction sheave once only (for approximately 180°) and the peripheral speed of the sheave is equal to the car speed. On account of the small arc of contact, a vee-sheave together with comparatively hard ropes is used. When the diameter of the sheave can be made equal to the distance between the car and counterweight supports, a diverting pulley is unnecessary.

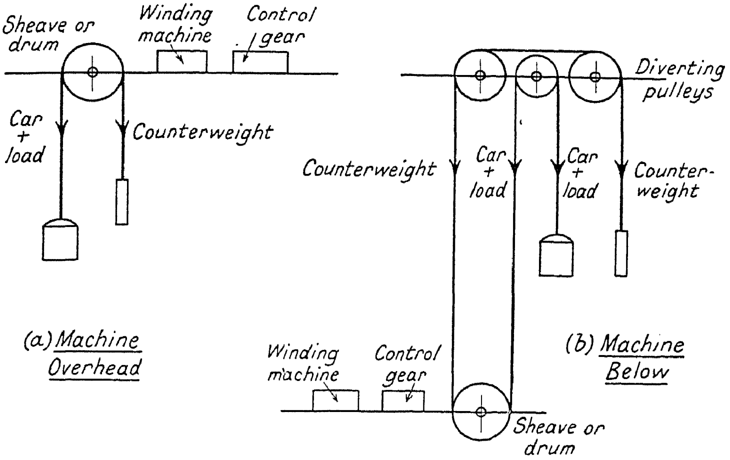
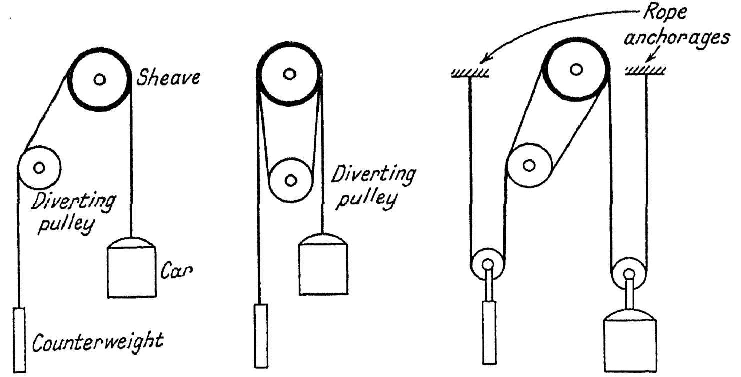
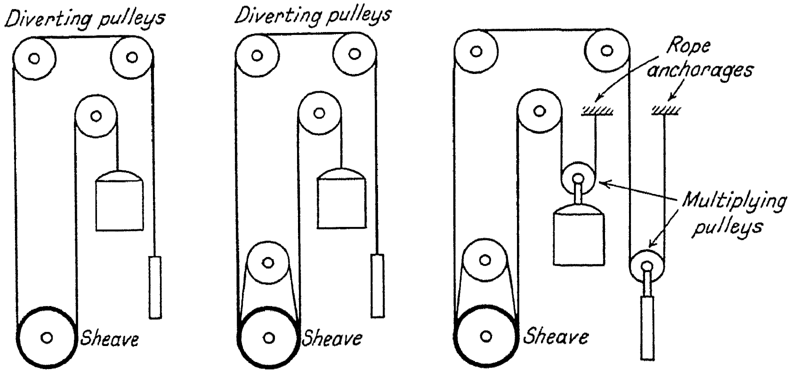


FIG. 23. DIAGRAM SHOWING LOADS ON OVERHEAD STRUCTURES

A *double-wrap* drive, sometimes referred to as a *full-wrap* or *cross-over* drive, is shown in Fig. 24 (*b*). The lifting ropes pass from the car around the sheave, pulley, sheave again, pulley, and thence to the counterweight if the pulley is not directly under the sheave. It is thus seen that the ropes wrap the sheave for approximately 360°. The pulley is placed directly under the sheave as in Fig. 24 (*b*) when the dimensions of the car and sheave permit. Most modern high-speed gearless lifts make use of this double-wrap drive which, because of the increased rope wrap, allows the use of U-shaped grooves on the sheave. This drive is also employed where the out-of-balance load is large, and there might be danger of rope slip with a half-wrap system. It should be noted that in these roping sketches only one rope is shown, but the number used may be as many



(a) Single Wrap (b) Double Wrap or Cross-over (c) Double Wrap (Two-to-One)



(d) Single Wrap (e) Double Wrap or Cross-over (f) Double Wrap (Two-to-One)

FIG. 24. SYSTEMS OF ROPING FOR TRACTION DRIVE

as six or even eight, whilst the minimum number which should be employed is three. Therefore, if six ropes are used with a double-wrap drive, then twelve grooves will be required on the sheave and twelve on the pulley when the pulley is not directly under the sheave.

Fig. 24 (*c*) shows a *double-wrap, two-to-one* roping system which gives a peripheral sheave speed of twice the car speed. The ropes are securely anchored to one of the structural beams and then pass around a multiplying pulley fixed to the counterweight, pulley, sheave, pulley, sheave, a second multiplying pulley fixed to the car frame, and finally to a second anchorage. This is usually employed on large capacity slow-speed goods lifts with the object of removing a portion of the load from the winding machine and, further, of permitting the use of a smaller number of lifting ropes, since these are not subjected to such stresses as with a one-to-one roping system. The two-to-one roping also enables gearless machines to be used for comparatively low car speeds of about 200 ft. per min. A disadvantage of the method however is the comparatively short rope life obtained due to the reverse bends employed.

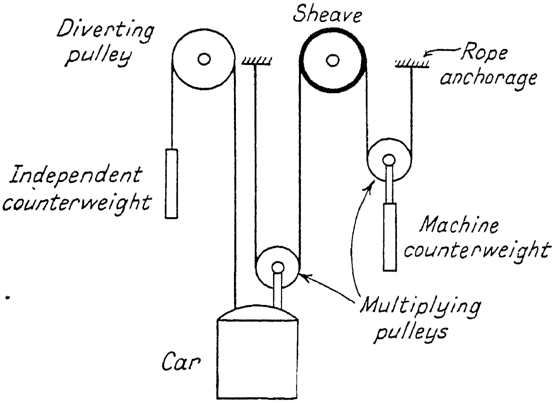
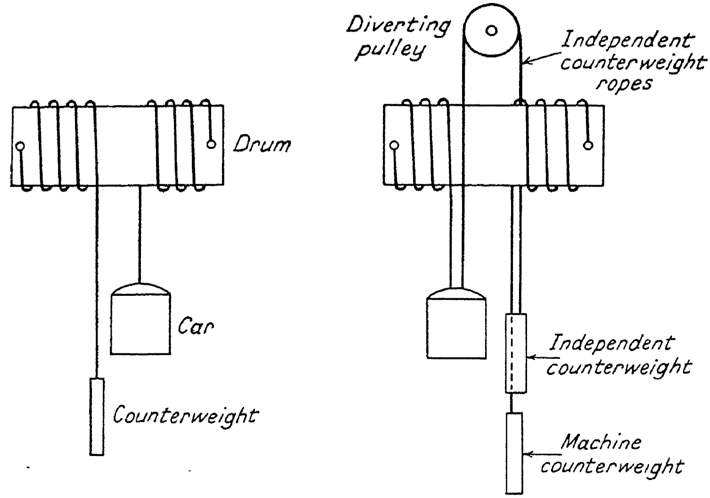


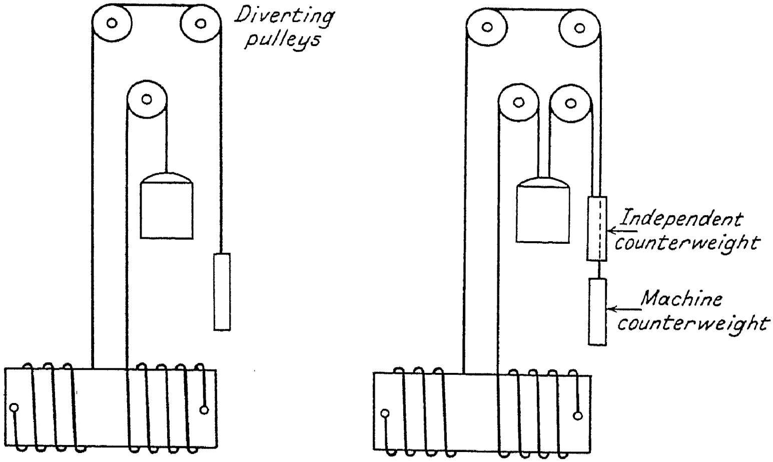
FIG. 25. SINGLE-WRAP TWO-TO-ONE ROPING
Two counterweights

For very heavy duty lifts, a method which has been employed still further to reduce the load carried by the winding machine makes use of a second counterweight as shown in Fig. 25. The addition of this independent counterweight causes some loss of traction, and its mass must be sufficiently low, therefore, to allow enough weight on the machine counterweight to maintain adequate traction. This lightening of the machine load is



(a) Drum Overhead (Machine Counterweight Only)

(b) Drum Overhead (Machine and Independent Counterweights)



(c) Drum Below (Machine Counterweight Only)

(d) Drum Below (Machine and Independent Counterweights)

FIG. 26. SYSTEMS OF ROPING FOR DRUM DRIVE

particularly desirable in the case of large gearless machines where the whole load, plus the weight of the motor, is normally carried by the motor bearings.

Fig. 24 (*d*), (*e*), and (*f*) show roping schemes similar to Fig. 24 (*a*), (*b*), and (*c*) respectively, but with the winding machine located below the well.

Drum Drives. A simple drum drive is shown in Fig. 26 (*a*), in which both car and counterweight ropes are securely anchored to the drum, and then pass to the car and counterweight respectively, via idle pulleys where necessary.

In the drive shown in Fig. 26 (*b*) an independent counterweight is employed in addition to the normal machine counterweight. The effect of this independent counterweight is to remove part of the car load from the drum shaft bearings and enable the machine counterweight to be reduced. These two counterweights are sometimes employed on large goods lifts, the independent counterweight being about 400 lb. lighter than the machine counterweight. Both counterweights run in the same guides, with the independent counterweight above, the machine counterweight cables passing through the independent counterweight.

Fig. 26 (*c*) and (*d*) show the drum located in the basement, the former employing a machine counterweight only, and the latter both machine and independent counterweights.

Compensating Ropes. These are sometimes fitted on long travel lifts with the object of making the load on the motor constant during a journey from one end of the well to the other. When the car is at the bottom of the well, the load on the motor is increased by the weight of the lifting ropes, which may be appreciable with high rises. Several methods of rope compensation are in use, but probably the best of these is that illustrated in Fig. 27. Ropes, equal in size and number to the lifting ropes, are secured

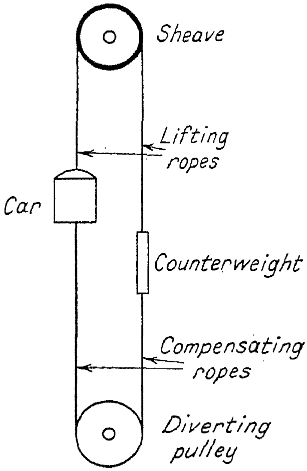


FIG. 27. COMPENSATING ROPES

to the car and pass to the counterweight via a diverting pulley fixed in the well bottom.

ROPES

Material. The lifting ropes employed on lifts are of stranded construction, each strand consisting of a number of steel wires. The steel used is either of special acid quality, termed *Grade A*, in which the phosphorus and sulphur contents are each not more than 0·04 per cent, or acid quality, termed *Grade B*, in which the phosphorus and sulphur contents are each not more than 0·05 per cent. Great strength and flexibility are the most important properties of a lift rope, the former being obtained by using a steel of high carbon content and the latter by using a stranded rope construction. The tensile strengths of the steel used in the manufacture of the ropes vary from 60 tons per in.^{2} to 120 tons per in.^{2}, although in America, mild steel of low carbon content and having a strength of about 40 tons per in.^{2} is sometimes used, particularly for difficult drives. The high tensile strengths are obtained by using a steel of moderately high carbon content, cold working by drawing the wires through a series of dies and, in addition, subjecting the steel to a heat treatment known as *patenting*. To obtain the best type of wire there must be a close adjustment of the carbon content and of the method of drawing.

Size. The specified size of a lift rope is the circumference of the circumscribed circle. Great care is necessary in measuring the diameter of this circle; the correct and incorrect methods of obtaining this are shown in Fig. 28. The standard sizes of lift ropes are shown in Appendix II.

Lays. Two methods are employed in laying the wires and strands of a lift rope, namely the *Albert* or *Lang's* lay and the *Ordinary* or *Regular* lay. In a Lang's lay rope the strands are laid up to form the rope in the same direction as its wires were twisted to make the strand as in Fig. 29 (*a*). In the ordinary construction, however, the strand wires are twisted in one direction and the completed strands are laid up in the opposite direction to make the rope as illustrated in Fig. 29 (*b*). The advantage of Lang's lay rope is that it offers a better wearing surface when in use, and therefore can reasonably be expected to give a longer life than ordinary lay rope. Furthermore, a

Lang's lay rope is more flexible than an ordinary lay rope. On the other hand, considerable experience is necessary in manipulating Lang's lay ropes as the tendency to kink and untwist is greater than with an ordinary lay. Hence, unless care is exercised in handling the rope, it may be incorrectly installed, with serious results to the length of service. In this country Lang's lay ropes are generally used, whilst in America the ordinary lay is very popular.

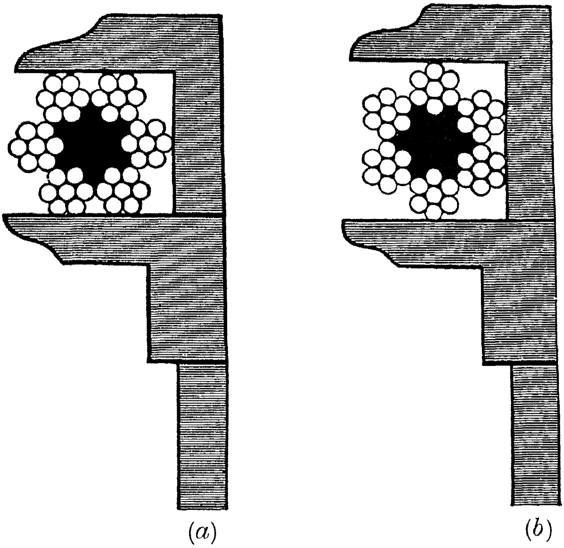


FIG. 28. METHOD OF GAUGING WIRE ROPE
(*a*) Incorrect (*b*) Correct
(*British Ropes Ltd.*)

The rope is usually of right-hand lay, which means that it is laid up to the right, or clockwise direction when looking at the rope end. Some ropes, however, are of left-hand lay, these being wound in the anti-clockwise direction looking at the end. Therefore, in addition to specifying the rope lay, the direction must also be stated, e.g. "Lang's lay, right hand." Fig. 29 (*a*), (*b*), and (*c*) show right-hand Lang, right-hand ordinary, and left-hand ordinary lays respectively. In some sets of lift ropes, right- and left-hand ropes are used in an effort to produce a non-rotating combination. For example, if four lifting ropes

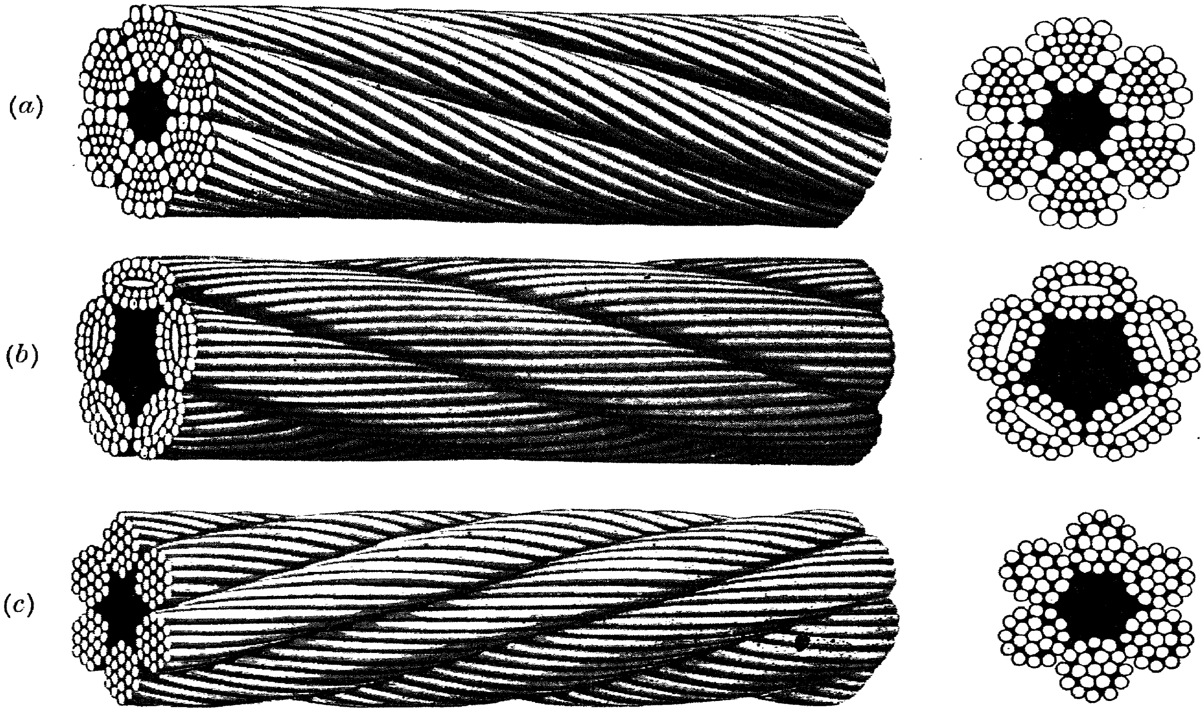


FIG. 29. TYPES OF ROPE LAYS

(*a*) Lang's lay, right hand. (*b*) Ordinary lay, right hand. (*c*) Ordinary lay, left hand
(*British Ropes, Ltd.*)

are installed, two ropes would be of right-hand lay and the other two of left-hand lay.

The length of lay of a rope is the distance, parallel with the axis of the rope, in which a strand makes one complete turn about the axis of the rope. The lay of the strand, similarly, is the distance in which a wire makes one complete turn about the axis of the strand.

Factor of Safety. The minimum factor of safety of the combined lifting ropes should be 15 for passenger lifts and 10 for goods lifts, based on the maximum car load plus the weight of the car and the accessories. Although the above is usually specified and is termed the *rope factor of safety*, it does not give a true indication of the margin of safety, because in arriving at these figures several other important factors have been neglected. The principal of these are, the initial stresses in the wire caused during manufacture, the additional forces in the rope during acceleration, and the bending stress due to the passage over sheave and pulleys.

Round Strand Ropes. The ropes generally employed for lift work are round stranded and all British standard lift ropes of round strand construction consist of six strands. The number of wires per strand, however, varies, and depends upon the particular construction adopted. Steel of tensile strength from 60 to 120 tons per in.^{2} is employed in the making of the wires, the different grades and their breaking strengths being as follows—

Grade of Steel	Breaking Strength (tons per in.^{2})	Grade of Steel	Breaking Strength (tons per in.^{2})
Mild Patent Steel	60–70	Special Improved Patent	90–100
Patent Steel	70–80	Best Plough Steel	100-110
Best Patent Steel	80–90	Special Improved Plough	110–120

The standard British constructions of round strand lift ropes are as detailed below.*

(1) 6 × 12 AND FIBRE. This rope has six strands, each of which consists of a single layer of twelve wires laid around a

---

* British Standard Specification No. 329, *Round Strand Steel Wire Ropes for Lifts and Hoists.*

fibre core. The six strands are in turn laid up around a central fibre core. The core, as in all lift ropes, consists of jute, hemp, or manila impregnated with a special lubricant, the objects of the latter being to act as a lubricating medium for the internal parts of the rope and to assist the rope when at work, by reducing friction. Furthermore, the lubricant preserves the wires and cores from deteriorating from the results of damp, especially when not in actual use. The lubricant must be free from acid, of a penetrating nature, and not liable to harden or peel off. In this 6 × 12 rope all wires used are approximately of the same diameter and, compared with the solid strand ropes described below, there is a gain in flexibility at the expense of strength.

(2) 6 × 19. This is probably the most commonly used construction for lift work, each strand consisting of nineteen wires laid with one layer of twelve wires, around another layer of six wires, around one central wire, all wires being of the same diameter. The six strands are laid around an impregnated core, as described above, to form the rope.

(3) 6 × 19 SEALE. In this rope, wires of different sizes are employed in its construction. Each strand of nineteen wires is made up of an outer layer of nine large wires, then a layer of nine small wires and finally one central large wire. The six strands are laid around an impregnated core in the usual manner. This rope is stiffer than the 6 × 19 rope and is therefore not suitable for small diameter sheaves or pulleys, or when the drive has reverse bends in the roping system.

(4) 6 × 24. Each strand of this rope consists of twenty-four wires all of the same size laid in two layers, one of fifteen wires around another of nine wires around a fibre core. As with the other ropes, the six strands are laid around a central impregnated core.

NON-STANDARD LIFT ROPES. Other non-standard round strand constructions sometimes employed, particularly in America, are the 8 × 19 and the 6 × 37. The former is similar to the 6 × 19 rope but has eight strands, and the rope is slightly more flexible than the 6 × 19 construction. The strands of a 6 × 37 rope are laid up as in the 6 × 19, but with the addition of an outer layer of eighteen wires, the result being a particularly flexible rope. A further round stranded rope which is popular in America, employs the "Warrington" construction which, like the Seale rope, uses wires of different sizes. In the 6 × 19 Warrington rope three wire sizes are employed. Each strand is formed of an outer layer of twelve wires which are alternately of large and small diameters, then a layer of six wires of medium diameter, and finally a central medium diameter wire. The six strands are laid up to form the rope in the usual manner. Like the Seale rope, the Warrington rope suffers from lack of flexibility. Some round strand rope sections are shown in Fig. 30.

Ropes of Special Strand Construction. The British standard grades of steel used for lift ropes which have specially shaped strands are as follows—

Grade of Steel	Breaking Strength (tons per in.^{2})	Grade of Steel	Breaking Strength (tons per in.^{2})
Best Patent Steel .	80–90	Best Plough . . .	100–110
Special Improved Patent . .	90–100	Special Improved Plough .	110–120

The quality of the steel is the same as that for round strand ropes. The two standard constructions of these flattened strand ropes are known as 5/27, 28, or 29 *oval* and 6/25 *F*. The 5/27 oval (16/11/4) construction is the one generally adopted for lifts.

(1) 5/27, 5/28, OR 5/29 OVAL. This rope is made of five oval strands laid around an impregnated fibre core. Each strand consists of twenty-seven, twenty-eight, or twenty-nine wires laid in two layers around a core consisting of a flat wire, an elliptical wire, or a flat strand of a number of round wires.

(2) 6/25 F. Six flattened strands are laid around an impregnated core to form this rope. The strand construction is twelve large wires laid around twelve smaller wires around a triangular shaped core which may consist of one or more shaped wires or one or more round wires.

The manufacture of flattened strand ropes was the logical development of the desire to produce a rope which, by reason of its power to resist abrasion, would give a longer life than did the round strand rope. It will be readily seen that with ropes of this type, frictional wear is spread over a greater number of the outer wires of the rope. In a round strand rope the wear is taken on one wire in each strand when the rope is new, and these wires are considerably reduced in sectional area before any appreciable wear is taken on the adjacent wires. In the flattened strand construction, owing to the friction being distributed over a greater external surface, the wear is much more even and the loss of sectional area of the vital outside wires much slower. Owing to the smooth surface and more nearly circular cross-section obtained with a flattened strand rope, the wear on sheaves and pulleys is reduced to a minimum. Flattened strand ropes show approximately 150 per cent more wearing surface than round strand ropes. Special strand rope sections are shown in Fig. 31.

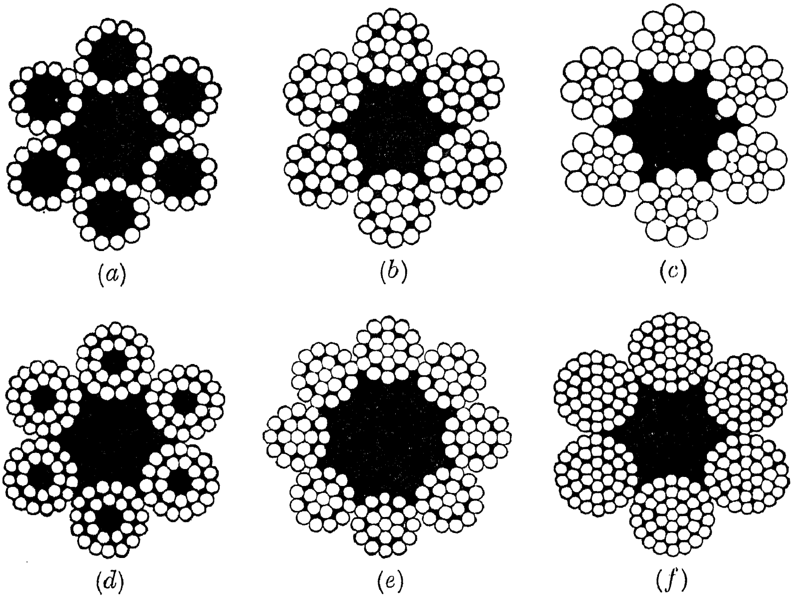


FIG. 30. ROUND STRAND ROPE SECTIONS

(a) 6 × 12 and fibre
(b) 6 × 19
(c) 6 × 19 Seale (9/9/1)
(d) 6 × 24
(e) 8 × 19
(f) 6 × 37

(*British Ropes Ltd.*)

Preformed Ropes. A special process known as *preforming* was introduced into this country from America about twelve years ago and is now incorporated in the manufacture of what are termed *preformed* ropes. In a rope of this type the strands are passed through a preforming head which gives to the wires the exact final shape which they will take up in the completed rope. In the manufacture of ordinary rope, the wires are held forcibly in position throughout the life of the rope, as can be seen by cutting such a rope at any point, when the strands and wires will immediately fly apart. Preforming the wires prevents this, as they all lie naturally in their true positions, free from internal stress. Lang's lay or ordinary lay ropes can be preformed; such ropes are sold under various trade names, probably the best known being the "Bluestrand Tru-lay."

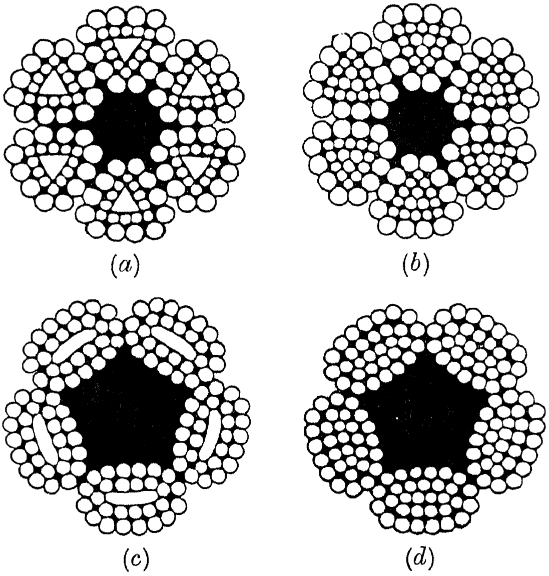

(*a*) (*b*)
(*c*) (*d*)

FIG. 31. SPECIAL STRAND ROPE SECTIONS

(*a*) 6/25 F (12/12/triangle) (*c*) 5/27 oval (16/11/oval)
(*b*) 6/25 F (12/12/3) (*d*) 5/27 oval (16/11/4)

(*British Ropes Ltd.*)

Although the initial cost of a preformed rope is greater than that of a corresponding rope of ordinary construction, the manufacturers claim that the many advantages of this rope far outweigh its extra cost. The advantages of this rope which have been borne out by practical experience may be summarized as follows—

(i) The rope is completely "dead" due to the reduction of internal stresses.

(ii) It has longer life due to the uniform distribution of, and the large reduction in, the internal stresses. This claim has been confirmed both by practical experience and by laboratory tests. Regarding the latter, the Third Report of the Institution of Mechanical Engineers Wire Ropes Research Committee states that on pulleys of corresponding diameters, Tru-lay ropes are distinctly superior in 6 × 19 ordinary lay ropes, particularly under the severe conditions imposed by the use of small pulleys. In summarizing, the report states that Tru-lay ropes were superior to those made by the usual method of manufacture, particularly on small pulleys and in 6 × 7 construction (not a lift rope).

(iii) The load is evenly balanced on individual strands and wires.

(iv) There is no tendency to high strand even under the severest conditions.

(v) When the outer wires break from long wear there is no tendency for them to fray out from the body of the rope, but they continue to lie in their proper places. This prevents damage to adjacent wires and to sheaves and pulleys.

(vi) It is more easily spliced as there is no need to seize the strands.

(vii) There is less tendency to "kink" than with ordinary ropes.

Preformed ropes are now being used in increasing numbers for lift work.

ROPE FASTENINGS

No car or counterweight rope should be repaired or lengthened by splicing, continuous lengths being invariably employed. Several methods are used for terminating the ropes at the car and counterweight, the best and most generally adopted being by *spliced return loops*, *clipped return loops*, or individual *tapered babbited sockets.* Loops must not bear directly on their fixings but must be lined with proper thimbles. In all cases the fastenings should be capable of sustaining a load of not less than 80 per cent of the ultimate strength of the undisturbed rope.

Spliced Ends. Splicing forms a satisfactory method of terminating a rope end, but care is necessary in forming the splice and the work should be carried out by an expert, to secure the best results. The rope is passed around a thimble, and sufficient free end of the rope left to form a splice of adequate length; after which the core is cut out from the free end. The free strands are opened out and each strand threaded through those of the main rope according to a definite schedule. Special tools are used to facilitate the operations of opening out the main rope strands and inserting those of the free end. When the splice has been made, any unevenness may be removed by carefully pounding with a wooden mallet, thus leaving a perfectly uniform exterior. Finally, the splice is carefully bound with either hemp or fine stranded wire as shown in Fig. 32. The lengths of satisfactory splices should be approximately as follows—

Circumference of Rope (in.)	Length of Splice (in.)	Circumference of Rope (in.)	Length of Splice (in.)
1	7	2½	19
1¼	9	2¾	21
1½	11	3	24
1¾	13	3¼	27
2	15	3½	30
2¼	17		

Bulldog Clips. Clips form an effective method of fastening rope ends provided they are of good design, of the proper size, and are correctly fitted. They have an advantage over other methods of fixing in that the rope can be more readily adjusted to take up stretch. The correct method of fixing these clips is shown in Fig. 33. For ropes up to 3 in. circumference at least three clips per rope end are recommended, for ropes over 3 in. and up to 4 in. in circumference four clips should be used, and for ropes over 4 in. in circumference five clips per end. After the clips have been fitted it is advisable, the following day, again to tighten up the nuts, as it is often found this is necessary owing to the rope squeezing down.

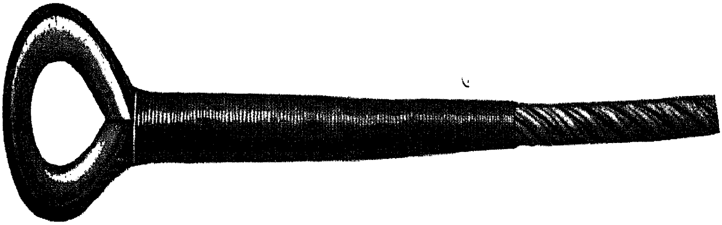


Fig. 32. Lift Rope Thimble and Splice

(*British Ropes Ltd.*)

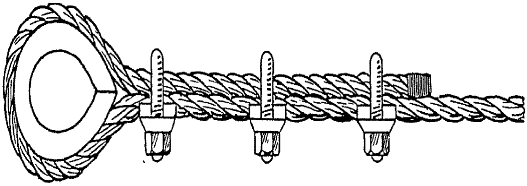


Fig. 33. Correct Method of Fitting Bulldog Grips

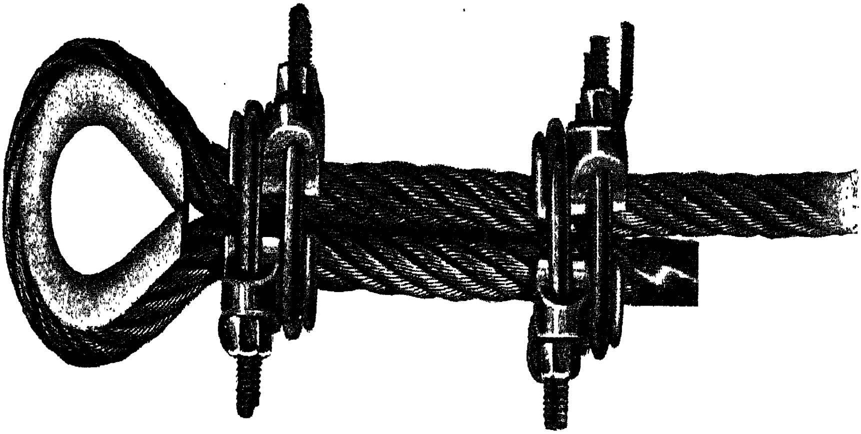


Fig. 34. Bullivant's Double Throat Clamp

(*British Ropes Ltd.*)

The clips must always be fitted so that the castings are on the loaded rope, or in other words, the U-bolts must always be on the short end of the rope.

An improved form of clip known as "Bullivant's Double Throat Clamp" is shown in Fig. 34. This clip is claimed to be more effective than the ordinary bulldog pattern as it prevents the crushing of the rope which occurs when the ordinary clamps are used.

Sockets. When properly made, the white-metal and socket method of rope capping is probably the strongest known, but great care must be taken to see that the proper alloy is used at the right temperature, and that the wires are perfectly clean and free from grease. An open tapered socket is shown in Fig. 35. Several methods are employed for fitting the sockets, one of the best of which is as follows—

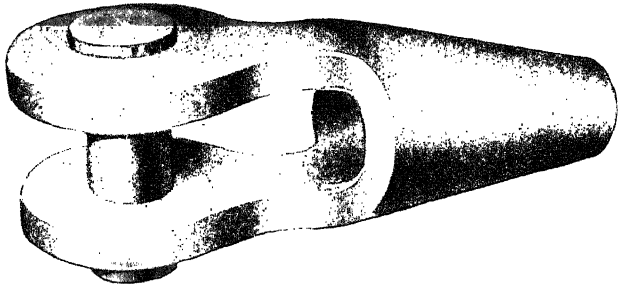


FIG. 35. OPEN TAPERED SOCKET
(British Ropes Ltd.)

The end of the rope to be socketed should be bound with soft iron wire for at least one inch more than the length of the chamber, and again above this length for a further six or eight inches. After placing the socket on the rope, the first binding should be removed, the rope end unlaid, and each individual wire straightened out so that the group of wires resembles a brush. Each wire should then be turned over to form hooks, facing inwards to the centre of the rope, and the fibre centre cut out. Each wire must be properly cleaned, preferably with petrol, which quickly takes away any grease or dirt and leaves the wires dry. After this the wires should be roughened with emery cloth. When all the wires have been cleaned they are drawn into position in the socket. The socket is then slightly heated to prevent the too rapid chilling of the white metal, thus ensuring its penetration. After this the socket is fixed in a vice and waste or clay wrapped round the rope, under the socket, so as to plug the mouth of the socket and prevent the metal running through. Some powdered resin should then be dusted amongst the wires. The metal used must have a low melting point so as not to anneal or take the temper out of the wire and, further, must have practically no contraction and set very hard. The melting point should be below 750° F. and excess heat must not be applied to the metal, otherwise the temper of the wires will be damaged. The correct temperature is readily indicated by inserting a chip of soft dry wood, e.g.

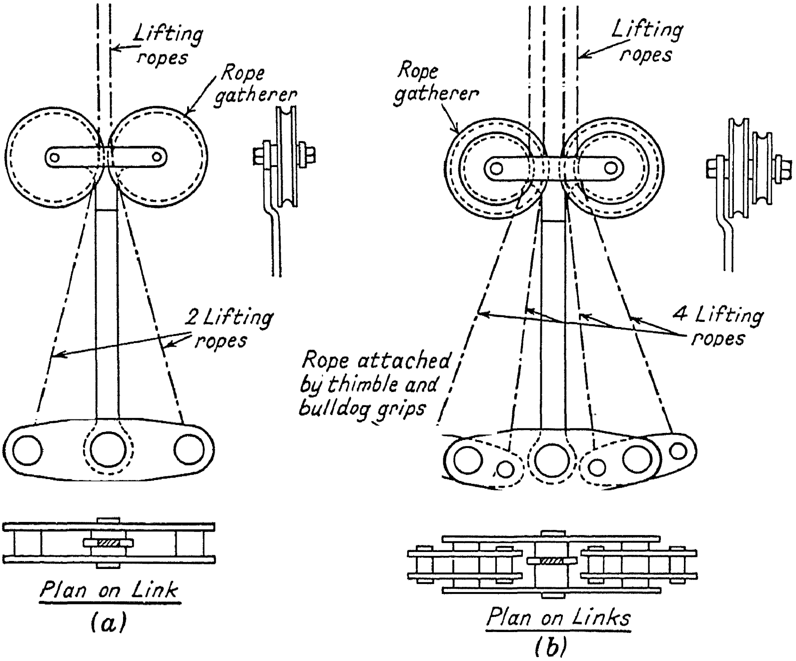


FIG. 36. ROPE EQUALIZING GEAR
(a) With two ropes (b) With four ropes

a match stick, which slightly chars when the metal is ready for use. After running in the white-metal, it should be allowed to cool naturally, after which it will be found that the cone has been formed throughout the whole length of the barrel.

Rope Equalizing Gear. Some means is invariably provided on lift ropes to equalize the load on the individual suspension ropes. Several different forms of equalizing gear are in use, but the principle of the simplest and probably most widely used is shown in Fig. 36 (*a*) and (*b*). With two ropes, each rope passes over a guide pulley or rope gatherer and the ends are attached, one at each side of a lever. This lever is free to rotate and takes up a position inclined to the horizontal, as one rope stretches more than the other. Thus each rope is subjected to the same tension. Three levers and four pulleys are used for a four-rope system as in Fig. 36 (*b*), the principle of operation being similar to that for two ropes.

CHAPTER V

MOTORS

Lift Motors : General. Several different types of motors suitable for lift work are available, the particular motor chosen depending upon the supply characteristics, car speed, and quality of service to be provided. For many purposes an ordinary commercial motor of speed between 750 r.p.m. and 1 200 r.p.m., and having certain special features, is suitable. Speeds of between 600 r.p.m. and 900 r.p.m. are usually preferred, whilst at speeds above 1 000 r.p.m. there is difficulty in obtaining the necessary degree of silence, even if special precautions are taken in the design of the motor room and the mechanical equipment. Furthermore, the higher the speed the more powerful the braking effort required, but on the other hand the price decreases as the speed increases. The graphs* in Fig. 37 give some idea how the kinetic energy and price vary with the motor speed.

The main requirements of a lift motor are, a starting torque equal to twice the full load torque, quietness, and low kinetic energy; the last feature is necessary to obtain rapid acceleration and deceleration, together with a minimum amount of brake lining wear. In addition, the armature or rotor shaft must be extended at the free end and made square, in order that the lift may be operated by hand, with a crank handle, in emergency and for effecting adjustments. The motor will be required to run in the same direction, either as a motor or as a generator, it being noted that when the load is a hoisting one, e.g. full load up, the machine functions as a motor, and when the load is overhauling, e.g. empty car up, the machine operates as a generator.

Size. The theoretical horse-power of the motor required to drive any lift is calculated as follows—

Assume that the maximum car load is 10 cwt., the maximum speed 250 ft. per min., and that the counterweight is equal to the car plus 50 per cent maximum load—

---

* "Electric Motors," by K. W. D. Roberts, *Metro. Vick. Gazette*, May, 1933.

The out-of-balance load = 5 cwt.

$$\text{i.e. h.p.} = \frac{5 \times 112 \times 250}{33\,000} = \underline{\underline{4{\cdot}25.}}$$

In practice, the horse-power required for satisfactory service will be considerably more than the theoretical horse-power, the actual amount depending upon the overall mechanical efficiency of the lift, which may be anything between about 30 per cent and 60 per cent (this varying with the size of the lift and the drive employed). Suitable motor sizes for various car loads and lifting speeds are shown in the table on p. 58.

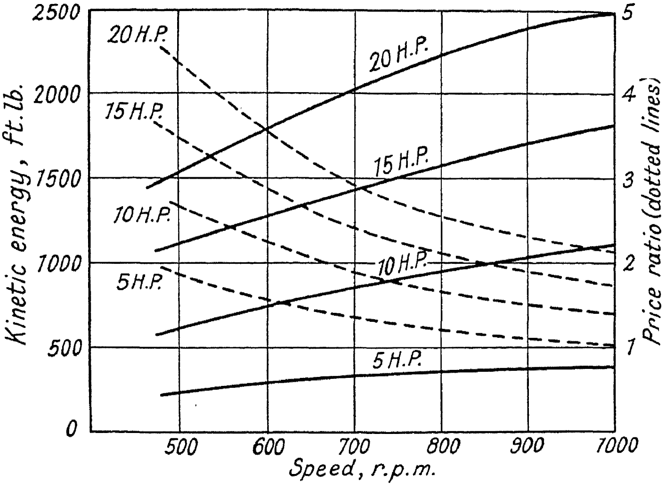


Fig. 37. Graphs showing Variation in Price and Kinetic Energy with Motor Speed

(*Metropolitan Vickers Gazette*)

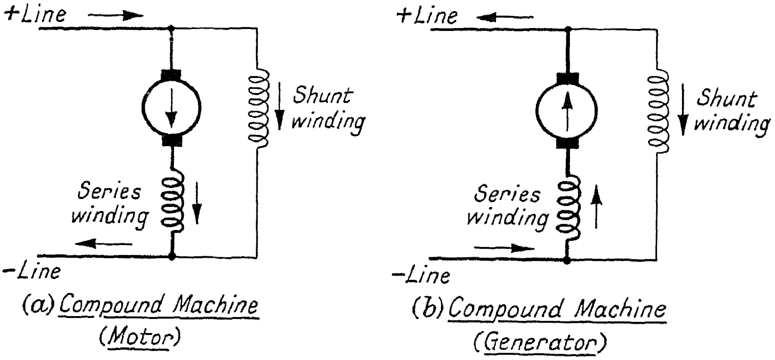
The figures quoted in the table are applicable to lifts with low efficiency irreversible worm gearing, and with the counterweight balanced for half the maximum car load.

DIRECT CURRENT MOTORS

Motors for Car Speeds up to about 120 ft. per min. A single-speed shunt or compound wound motor is employed for these

Car Speed (ft. per min.)	Maximum Car Load (cwt.)					
	5	10	15	20	30	40
50 . . .	2	3·5	5	6	8·5	11·5
100 . . .	3	5·5	8	10	15	20
150 . . .	4	8	11	15	21	28
200 . . .	5	10	14	18	27	37
250 . . .	6	12	17	23	34	45
300 . . .	7	14	21	27	40	54

low speeds, the larger sizes being equipped with commutating poles to give sparkless commutation in both directions of rotation. With car switch control, however, single-speed motors are sometimes used for car speeds up to 150 ft. per min. As previously mentioned, the machine must be capable of running as a generator or a motor, and this entails special arrangements being made in the case of a compound motor. The diagrams in Fig. 38 show the directions of the currents in the windings of a compound wound motor when "motoring" and "generating." When operating as a motor, both fields are in the same direction,



(a) Compound Machine (Motor)

(b) Compound Machine (Generator)

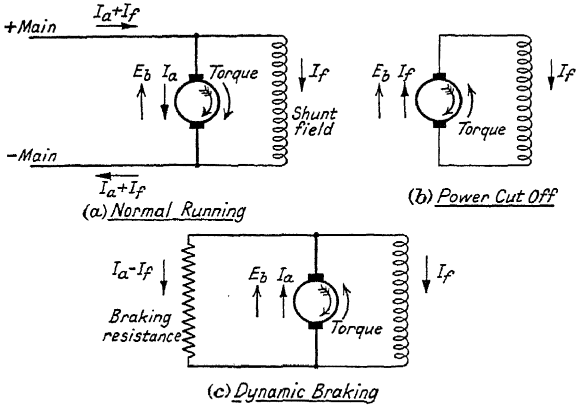
FIG. 38. CURRENTS IN WINDINGS OF A COMPOUND WOUND MACHINE

but on change over to a generator, the back e.m.f. becomes greater than the applied voltage, and the two fields oppose each other. This results in a weakened field, reduced dynamic braking power, and an increase in the car speed. It is therefore necessary to arrange that the controller cuts out the series winding when the full speed has been reached, the object of the series winding being to provide a high starting torque.

When the main contactor closes, the brake shoes are released and the shunt field is energized via the starting resistances. Two methods are employed to cut out the starting resistances and thus obtain acceleration. In the first method, an oil dashpot or a mechanical time relay is used to control the movement of the accelerating magnet plunger, and by this means the steps of starting resistance are cut out on a definite time basis, determined by the dashpot or relay adjustment. With the second method the accelerating switch coil is connected across the motor armature and the cutting out of the starting resistances is thus dependent upon the motor speed. At the instant of closing the armature circuit, the voltage across the armature is small, but as the motor speed rises the armature voltage increases. Hence, the voltage across the accelerating magnet coil gradually increases and its contact arm cuts out the starting resistance at a rate proportionate to the increase in motor speed. The series field is cut out of circuit immediately the starting resistance has all been cut out.

Deceleration is obtained by re-inserting the starting resistance and by connecting a diverter resistance across the armature, thus producing a slow levelling speed, not subject to such wide variations in speed as with a series resistance. Immediately the main contactor opens, a braking resistance is placed in parallel with the armature. By this means the kinetic energy of the lift is converted to heat, which is dissipated in the resistance, and the resulting dynamic braking assists the mechanical braking action. The effect of the dynamic braking resistance across the armature is shown in Fig. 39. In (*a*), which shows the normal running conditions, the back e.m.f. E_b is in the opposite direction to that of the main voltage and the armature current I_a. When the power is cut off, the conditions are as shown in (*b*), the field current I_f, which is almost equal to the normal value, being maintained by the armature back e.m.f. The addition of the braking resistance gives the conditions shown in (*c*), the reversed armature current causing a reverse braking torque, the value of which depends upon the magnitude of the parallel resistance. Hence the rate of deceleration caused by dynamic braking may be low or high, depending upon whether a high or low value of resistance is employed.

Motors of about 15 h.p. and over are sometimes provided with an additional shunt field in parallel with the main shunt field, the auxiliary field being automatically cut out as the speed rises, and re-inserted during the slowing down period. This auxiliary field increases the starting torque and improves the speed regulation.



(*a*) Normal Running

(*b*) Power Cut Off

(*c*) Dynamic Braking

FIG. 39. DYNAMIC BRAKING WITH D.C. MOTOR

Motors for Car Speeds between about 120 ft. per min. and 350 ft. per min. Two-speed motors, having speed ratios of 2–1, 3–1, or 4–1, are used in order to obtain a slow speed for efficient landing. The motor is similar to that used for single-speed working except that it is arranged for shunt regulation. In a typical two-speed motor having speeds of 400 r.p.m. and 800 r.p.m., acceleration from zero is obtained by cutting out the series starting resistance, as for a single-speed motor. The field is at full strength (all resistance out) whilst running up to 400 r.p.m. Increase from 400 to 800 r.p.m. is obtained entirely by shunt field weakening, effected by inserting field resistance. Deceleration from 800 to 400 r.p.m. is obtained by short-circuiting the field resistance, and below 400 r.p.m. by introducing the series starting resistance and shunting the armature by means of a diverter resistance, as for a single-speed motor. Dynamic braking is also resorted to, prior to the application of the mechanical brake.

Motors for Car Speeds above 350 ft. per min. During recent years there has been a demand for car speeds above 350 ft. per min., due to the withdrawal of certain building restrictions, and the consequent erection of higher buildings. In this country the maximum car speed at present is about 600 ft. per min., whilst in America speeds up to 1 400 ft. per min. are employed in the "skyscrapers," whose heights in some cases exceed 1 000 feet. With these high speeds it has been possible to make use of a specially designed slow-speed d.c. motor, the shaft of which is coupled directly to the driving sheave, without the use of gearing. This reduction in motor speed and elimination of gearing results in a smaller inertia of moving parts. The motor, brake, and sheave are mounted on a common bedplate to form a single unit, and it is thus seen that the

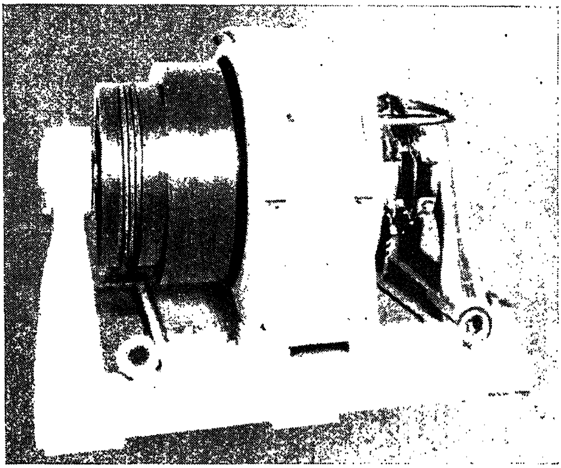


FIG. 40. GEARLESS MOTOR
(Mechanical brake removed)
(*Metropolitan Vickers*)

motor bearings carry the load of the car, counterweight, and the pull due to the ropes around the idle pulley (if a double-wrap drive) in addition to the weight of the motor armature, sheave, and brake drum. The motor is a shunt wound machine having a speed of between 50 r.p.m. and 120 r.p.m., depending on the duty, and is not usually equipped with commutating poles, these being scarcely necessary at such low speeds. On account of its large size it is not practicable to provide a range of speed of more than 1·5 to 1 by field control. In the earlier gearless machines the speed was controlled rheostatically by means of a combination of series and parallel resistances as in the case of the ordinary d.c. motor, but the best and most modern method is the application of the variable voltage or Ward-Leonard principle (see Chapter VI). The major part of the speed variation is accomplished by varying the voltage applied to the motor, the remaining small change being effected by field control. A gearless motor, without its mechanical brake, is shown in Fig. 40.

ALTERNATING CURRENT MOTORS

POLYPHASE SUPPLY

Motors for Car Speeds up to about 120 ft. per min. The single-speed squirrel-cage motor is suitable for these low speeds, although it suffers from the disadvantages of high starting current and a tendency to overheat if the duty is severe. The slip should be kept within reasonable limits to avoid too great a speed variation. It is necessary, also, that the motor should develop a high torque for starting and accelerating, but this means that it will inherently have a high slip, so that some compromise must be made in the design. Further, a low slip is obtained by reducing the rotor resistance, which is an indication that the starting current will be high. In practice, the starting current should not exceed about 400 per cent full load current, and the starting torque should be about 200 per cent full load torque. These motors are often switched directly across the lines, but it is frequently necessary to provide smoother acceleration by the use of starting resistances in the stator circuit. The short-circuiting of these resistances is controlled by an air or oil dashpot.

Better speed regulation and smoother acceleration are obtained by using a wound rotor motor which is accelerated by cutting out the rotor resistances in one or more steps, these being controlled by dashpots. Although the speed can be varied by rotor resistance, this machine is essentially single-speed, as the insertion of rotor resistance results in low efficiency and poor speed regulation. Hence, the rotor resistance is used for the short starting period only, when the loss in performance is unimportant. The connexions for a single-speed slip-ring motor with two steps of starting resistance are shown in Fig. 41.

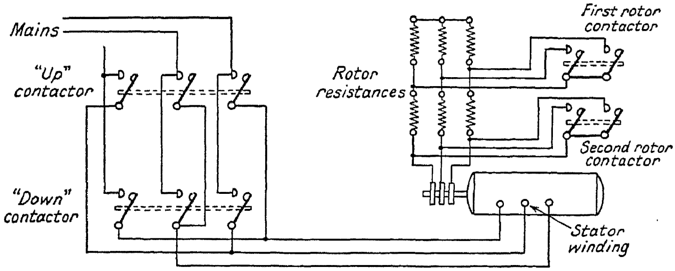


Fig. 41. Single-speed Slip-ring Motor with Two Steps of Rotor Resistance

Motors for Car Speeds between about 120 ft. per min. and 350 ft. per min. For these car speeds it is necessary to employ one of the several available types of motors capable of running at more than one speed, in order to obtain a slow landing speed.

Squirrel-cage Induction Motors. The squirrel-cage induction motor can be adapted for pole changing by regrouping the stator winding to give two polar combinations corresponding to the two speeds. For one combination of poles, the coils in any one phase give poles of similar polarity around the machine, the opposite poles being induced in the spaces between the coils. By reversing every alternate coil, the poles produced are alternately north and south and only half the original number of poles is produced. Pole changing can therefore only be used when the two speeds required are in the ratio of two to one. One method of obtaining half the number of poles, i.e. double the speed, by this reversal of current in half the winding, is shown in Fig. 42. The winding is connected in star for the larger number of poles, and in two parallel star windings for the smaller number of poles. For the direction of rotation to remain unchanged when the poles are changed, two of the phases must be reversed in relation to the line wires. The motor starting and running connexions are shown in Fig. 43. Another method, in which the windings are connected in delta for the larger number of poles, and in two parallel star circuits per phase for the smaller number of poles, is shown in Fig. 44. This is a better method, as an improved performance is obtained and no reversal of line wires and phases is necessary to maintain the same direction of rotation. A further disadvantage of pole changing is that, if the coil pitch is correct for one of the polar combinations, it is inefficient for the other.

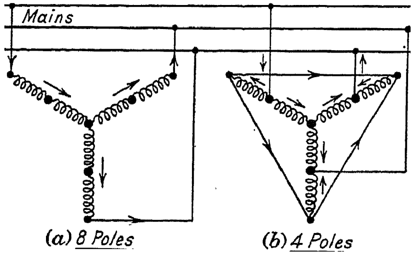


FIG. 42. STATOR WINDINGS OF TWO-SPEED SQUIRREL-CAGE MOTOR (Star—Two Parallel Star)

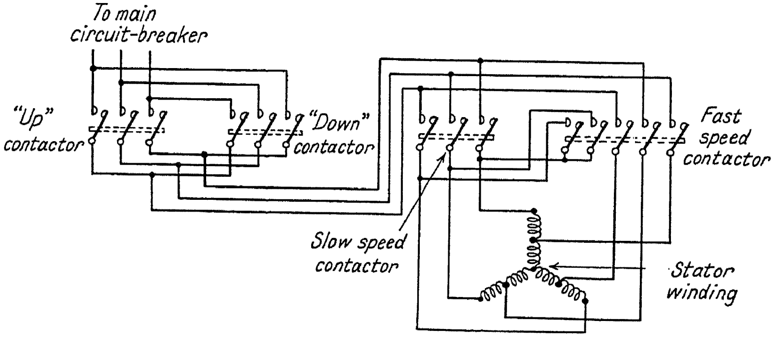


FIG. 43. TWO-SPEED SQUIRREL-CAGE MOTOR CONTROL CIRCUIT

In another form of two-speed squirrel-cage motor, two separate stator windings, wound in the same slots, are employed to give the pole change corresponding to the required two speeds. Ratios up to six to one are possible with this double wound motor, the high and low speed windings being cut in and out of circuit by means of a contactor. The disadvantage of this type is the complexity of the double winding and the difficulty of repair, especially if the damaged winding is the under one of the two.

These two-speed squirrel-cage motors are usually started up with resistance in the high-speed winding, whilst smooth deceleration is obtained by inserting a buffer resistance, either in the slow- or high-speed winding during transition to slow speed. Another method of effecting smooth acceleration with lift motors of this type is to employ an induction regulator in the motor supply circuit; the regulator applying the starting voltage gradually to the high-speed winding without the use of resistances. The induction regulator is a transformer with a variable ratio of transformation, and is built like an induction motor, the stator forming the primary, and the wound rotor the secondary. The rotor is not free to rotate but its position can be altered through one pole pitch by means of a small torque motor. This turning of the rotor varies the voltage applied to the high-speed winding, and results in very smooth acceleration.

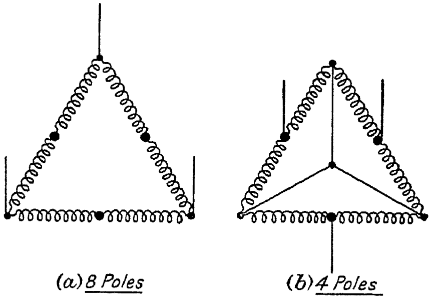

(a) 8 Poles (b) 4 Poles

FIG. 44. STATOR WINDINGS OF TWO-SPEED SQUIRREL-CAGE MOTOR
(Delta—Two Parallel Star)

SLIP-RING INDUCTION MOTORS. Speed changes, by the methods employed with squirrel-cage motors, may be obtained with a slip-ring motor, but this usually involves the use of two separate rotor windings arranged similarly to the stator windings. The rotor connexions must be changed at the same time that the stator connexions are changed and this, together with the slip-rings, involves extra complications in the control circuit, although an improved performance is obtained. The use of two rotor windings may be avoided, however, by carrying the rotor currents through internal short-circuited paths during one of the speeds, but this involves the loss of the slip-ring characteristics on one speed.

A method of producing two speeds with a wound rotor motor having only one rotor winding is described in the *Electrical Review* of 16th January, 1931. The rotor coils are grouped and pitched so that, although only one winding is employed, this reacts in a field having either of two polarities. This regrouping is possible for speed ratios of three to one and four to one, corresponding to 6/18 pole and 6/24 pole rotors, and for other ratios likely to be required in practice. The motor is started on the high-speed winding with rotor resistance in the usual manner, and slowed down by external resistance, which controls the rate of deceleration.

Slip-ring Variable Voltage Control. The Express Lift Co. have evolved a series of systems known as slip-ring variable voltage (S.R.V.V.) control, all covered by British Patents, which offer an effective solution to the difficulty of cheaply and effectively using an a.c. supply for car speeds up to 300 ft. per min. Of these, the one in general use by the Company, designated as their 1937 "T" type, employs a normal slip-ring induction motor, and depends for its efficiency upon three distinct steps of control, namely acceleration, running, and deceleration.

Acceleration is determined by the rate of decay of voltage induced in the rotor circuit as the rotor speed rises; a special voltage responsive relay circuit controls the amount of rotor resistance until full speed is reached, so that acceleration is rapid and smooth.

Running speed is dependent upon the natural speed of the motor, the synchronous characteristics of which are sufficiently marked to maintain the running speed substantially constant regardless of load variation.

Deceleration, upon the accuracy of which depends good levelling, is determined by the time taken for the lift to travel a predetermined distance. When the car approaches a floor at which it is required to stop, a signal is received by the controller which causes the application of a predetermined braking effort and the insertion into the rotor circuit of a suitable amount of resistance. This has more or less effect to slow the lift depending upon the load and the direction of travel. The car will take more or less time to travel between two predetermined points in the lift well, so that if signals are received to determine the

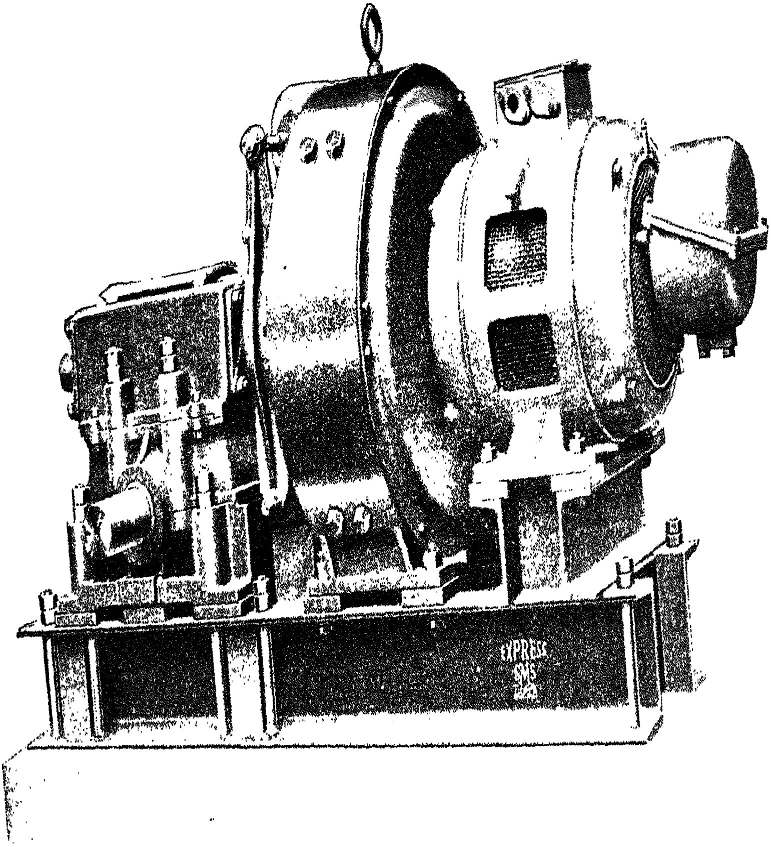


FIG. 45. SLIP-RING MOTOR WITH MAGNETIC BRAKE, FRICTION BRAKE, AND GEARING

(Express Lift Co. Ltd.)

actual moments when those two points are passed, a timing device may be started at one point and stopped at the other; this timing device being made to control the amount of eddy-current brake adjustment required to reduce the lift speed to a suitable creep value.

The timing device is constituted by a rotary selector switch arranged to be driven by electromagnetic means at an exact and predetermined speed over an arc of 25 contacts. Depending on the number of contacts swept by the selector wipers in the available time, several of a number of small contactors are energized to adjust the braking effort, so that the car always reaches the desired creep speed before entering the floor. This slowing is effected by an eddy-current brake. The car actually travels only a few inches before being finally stopped, at creep speed, which is ideally not more than one-tenth of full speed.

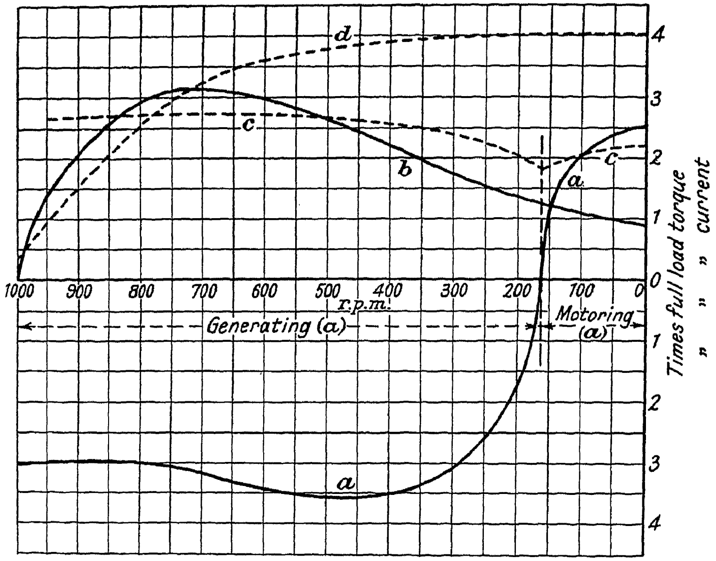


Fig. 46. Characteristic Curves of the Two Windings of Tandem Motor

(a) Torque of S.C. motor
(b) Torque of S.R. motor with no rotor resistances
(c) Current of S.C. motor
(d) Current of S.R. motor with no rotor resistances

(*Metropolitan Vickers Gazette*)

It is evident that if a car always enters a floor at a low and predetermined creep speed, the final braking needed to stop the car can be a constant quantity. The final stopping is performed by the usual type of electromagnet friction brake. The complete machine, which includes slip-ring motor, eddy-current brake, electromagnetic brake and gearbox, is shown in Fig. 45.

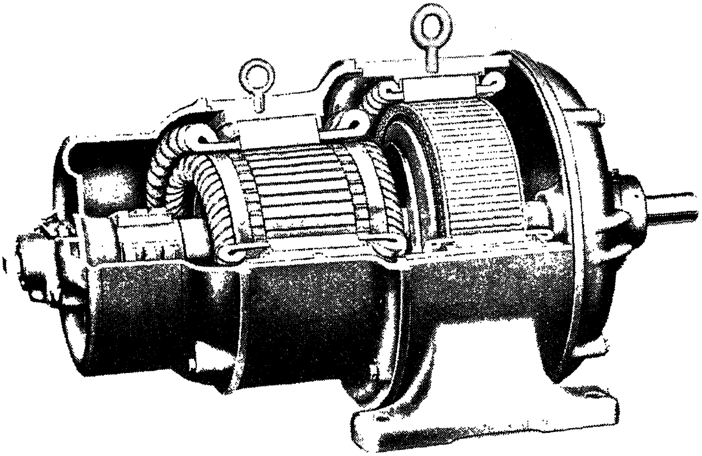


FIG. 47. PART SECTIONAL ELEVATION OF TANDEM MOTOR
(*Metropolitan Vickers*)

TANDEM MOTORS. The Tandem, two-speed a.c. motor, which has been employed on a number of recently installed lifts, consists of a wound rotor and a squirrel-cage rotor, forming the high- and low-speed sections respectively. These are assembled on the same shaft and the two frames bolted together to form a single two-bearing unit. Various speed ratios are obtainable and in a typical motor having a six-to-one ratio the speed obtainable from the wound rotor portion is 960 r.p.m. whilst the low speed from the squirrel-cage end is 160 r.p.m. In this particular motor, the slip-ring section is wound for 6 poles, and the squirrel-cage section for 36 poles. Approximate performance curves for the sections of this motor are shown in

Fig. 46,* from which it will be seen that if the lifting speed is at its maximum, this can be reduced to one-sixth, by transferring the supply from the slip-ring section to the squirrel-cage section. Both sections are magnetically and electrically independent internally and each is capable of producing twice the full load torque, for starting purposes. The slip-ring portion is of standard design for lift service, whilst the low-speed end should have low slip and high starting torque to ensure a constant speed at all loads. A part section of the motor is

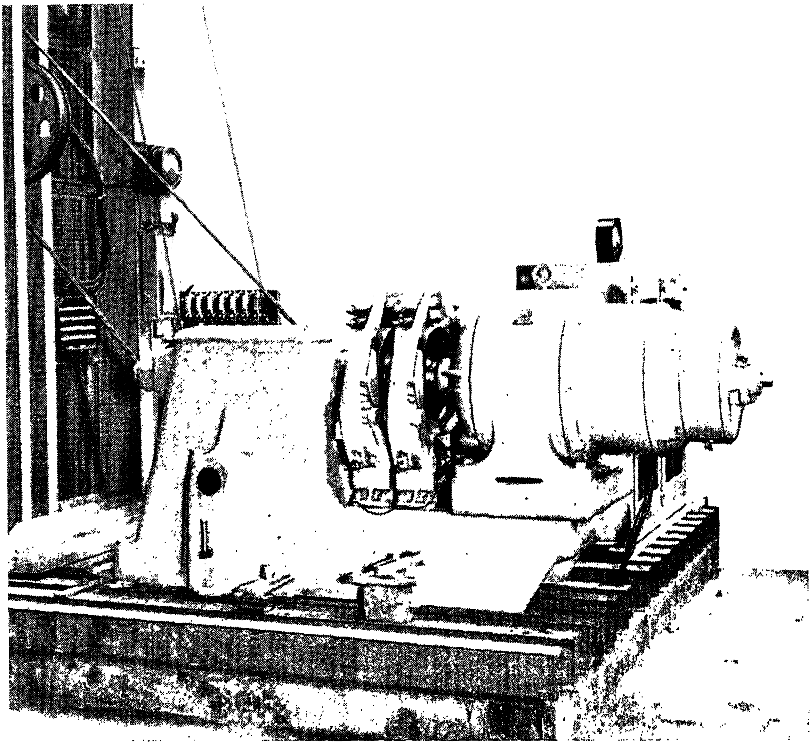


FIG. 48. LIFT MACHINE WITH TANDEM MOTOR
(Wm. Wadsworth & Sons)

---

* "Tandem Motors," by K. W. D. Roberts: *Metropolitan Vickers Gazette,* July, 1935.

shown in Fig. 47 and a complete tandem motor lift machine in Fig. 48.

It is usual to start up on the high-speed winding with resistance in the rotor circuit, the resistance being gradually cut out until final running speed is attained. To change from high to low speed, a switch disconnects the high-speed winding and another switch energizes the low-speed section. On change over to low speed, dynamic braking occurs, and from the characteristic curves it will be seen that a reverse torque, up to approximately four times full load torque, is obtained. The inertia of the rotating parts helps to smooth out the change, but it is also necessary to insert a buffer resistance or a choke coil in the star point of the squirrel-cage stator winding to prevent the deceleration from being excessive. The resistance is gradually cut out during decleration, leaving the slow-speed winding fully energized. The starting and running connexions for this type of motor are shown in Fig. 49.

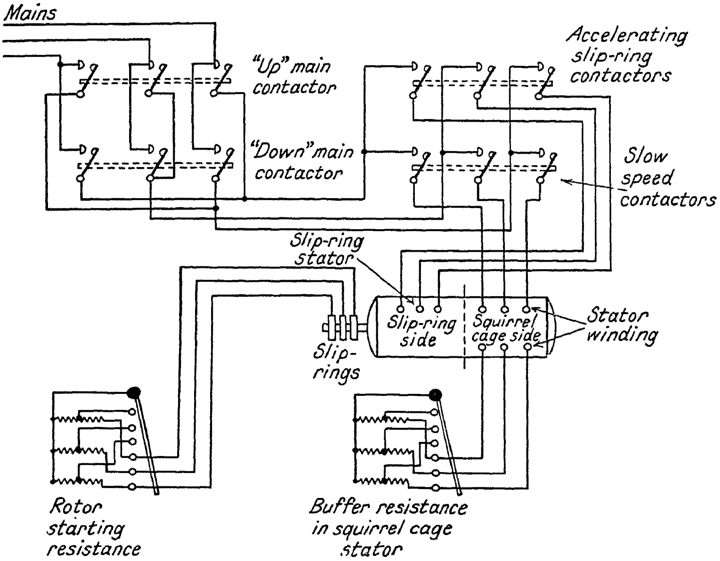


FIG. 49. TANDEM MOTOR CONNEXIONS

A.C. COMMUTATOR MOTORS. Motors of the variable speed, shunt commutator type have become popular for lift work during recent years, and speed changes of seven to one may be obtained in the smaller sizes, whilst changes as high as fifteen to one are possible in the larger sizes. The arrangement of the windings differs from that of the ordinary induction motor in that the primary winding is located on the rotor and the secondary winding on the stator. In addition to the primary winding, which is connected to the supply by means of slip-rings and brushes, a regulating winding is placed in the same rotor slots. This latter winding is connected to a commutator in a similar manner to the armature winding of a d.c. machine. The commutator is provided with two brush rockers which can be moved relatively to each other by means of a small pilot motor. One end of each phase of the stator winding is connected to a brush stud of one rocker and the other end of the phase to the corresponding brush stud of the opposite rocker. Hence, the greater the distance the two sets of brushes are moved apart, the greater will be the amount of regulating winding connected in series with the secondary. The pilot motor, by moving the brushes in this manner, varies the e.m.f. injected into the secondary winding, this e.m.f. being zero when the brushes connected to the ends of the same phases of the secondary are in line, i.e. in contact with the same segments. Under these conditions the motor runs as an ordinary induction motor at a speed slightly less than synchronous speed. The e.m.f. which is induced by the primary in the secondary, however, depends upon the speed of rotation, being zero at synchronous speed and reaching a maximum value at standstill. The effect of the injected e.m.f. is to compel the motor to change from synchronous speed to that at which the induced secondary e.m.f. balances the injected e.m.f. By rotating the brushes in one direction or the other, the injected e.m.f. is made negative or positive, resulting in speeds below or above the synchronous speed.

Resistances $R1$, $R2$, and $R3$ may be introduced in the secondary winding to obtain creeping speeds as shown in the diagram of the motor windings in Fig. 50. The insertion of resistance, however, adversely affects the characteristic, the speed drop from no load to full load being greater than for speed regulation by brush shifting alone.

Arrangements must be made to ensure that the pilot motor drives the brushes back to the slow speed position in the event of a stoppage from any cause. The pilot motor, which is frequently mounted on the main motor (see Fig. 51), is a small double-wound, two-speed, squirrel-cage motor driving a worm gear, the slow-speed and high-speed windings giving suitable brush speeds for acceleration and deceleration respectively.

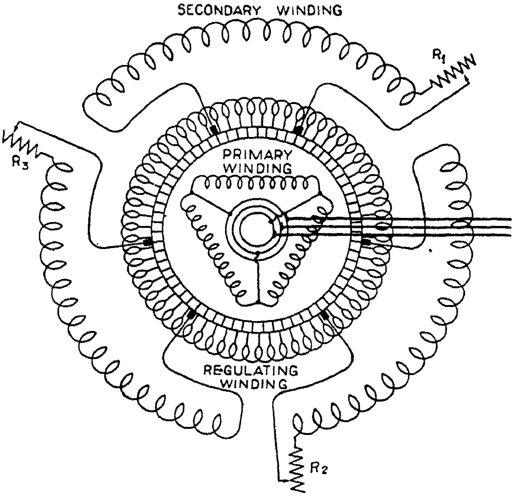


FIG. 50. DIAGRAM SHOWING ARRANGEMENT OF WINDINGS OF B.T.-H. TYPE CH A.C. COMMUTATOR MOTOR
(*B.T.-H.*)

The motor switching connexions are shown in Fig. 52. The operating coils of the accelerating and declerating contactors are controlled by mechanical switches operated by the pilot motor, these switches ensuring that only one contactor can operate at any one instant, and that the brushes are in their correct positions before starting.

The operating characteristics of this type of motor are very good and approach those obtained with variable voltage control; a smooth speed transition is obtained, the power factor is high over a considerable portion of the speed range, and the currents for starting and acceleration are smaller than with two-speed induction motors. Performance curves of the

British Thomson-Houston Co.'s "Type C.H." lift motor are shown in Fig. 53 (*a*), (*b*), and (*c*). A group of three lifts equipped with these motors is shown in Fig. 54.

The disadvantages of the commutator type motor are its high cost and the fact that it is rather noisy during operation. Some idea of the relative costs of induction and commutator motors is given in the curves in Fig. 55.*

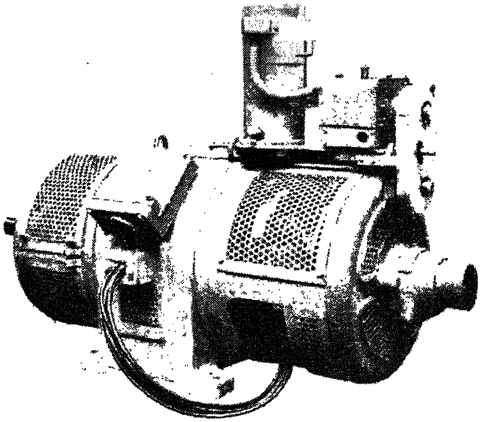


FIG. 51. A.C. COMMUTATOR LIFT MOTOR
(*B.T.-H.*)

Motors for Car Speeds above 350 ft. per min. Geared a.c. motors are in use for speeds above 350 ft. per min., but these are exceptions rather than general practice. It is not practicable to produce a gearless a.c. machine, and the gearless d.c. motor operating from a variable voltage motor generator set is the method usually employed. The mains motor is invariably of the squirrel-cage induction type.

SINGLE-PHASE SUPPLY

Motors for Car Speeds up to about 120 ft. per min. REPULSION-INDUCTION MOTORS. This motor starts as a repulsion

---

* "Elevator Motors," by K. W. D. Roberts: *Metropolitan Vickers Gazette*, May, 1933.

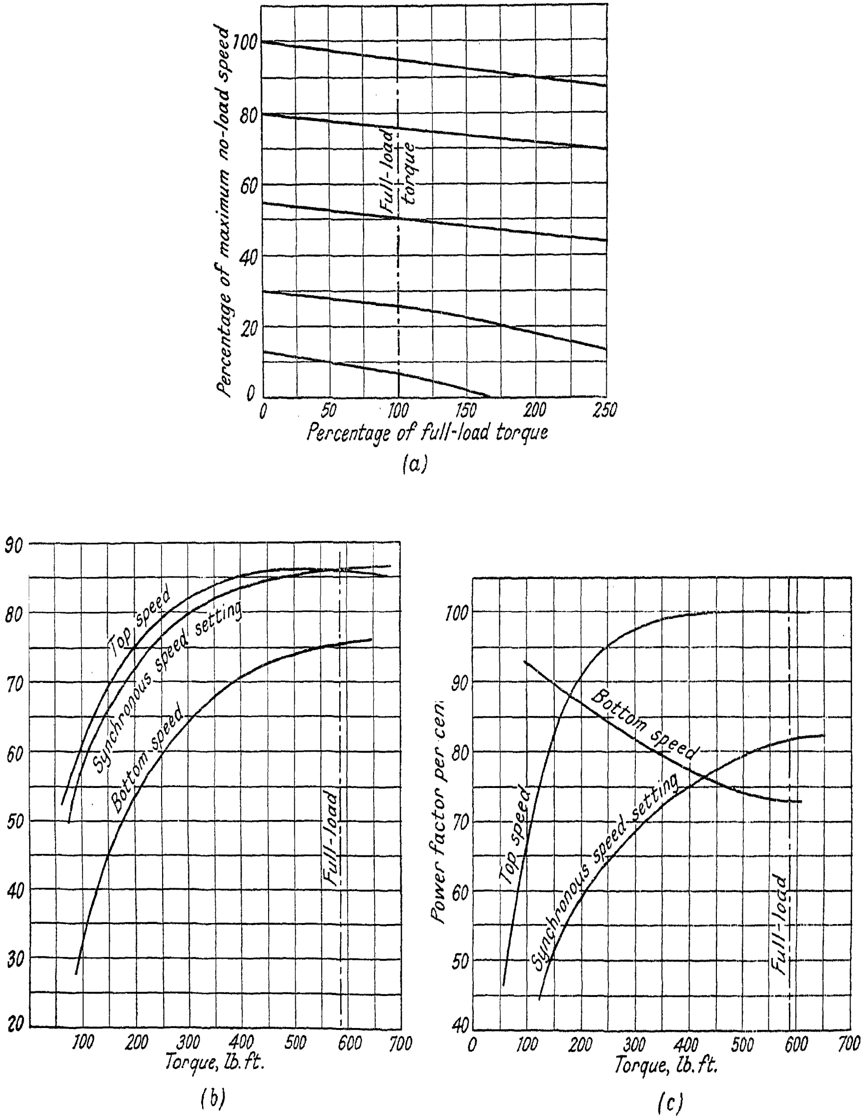


FIG. 53. PERFORMANCE CURVES OF B.T.-H. TYPE CH LIFT MOTOR

(*a*) Torque/speed curves with long speed range controlled throughout by brush-gear
(*b*) Efficiency curves for 80/27 h.p. motor at various speeds
(*c*) Power factor curves for 80/27 h.p. motor at various speeds

(*B.T.-H.*)

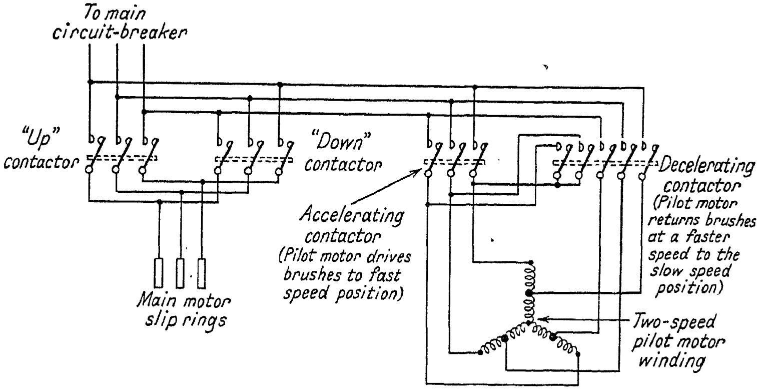

To main circuit-breaker
“Up” contactor
“Down” contactor
Accelerating contactor
(Pilot motor drives brushes to fast speed position)
Main motor slip rings
Decelerating contactor
(Pilot motor returns brushes at a faster speed to the slow speed position)
Two-speed pilot motor winding

FIG. 52. THREE-PHASE A.C. COMMUTATOR MOTOR WITH TWO-SPEED PILOT BRUSH MOTOR

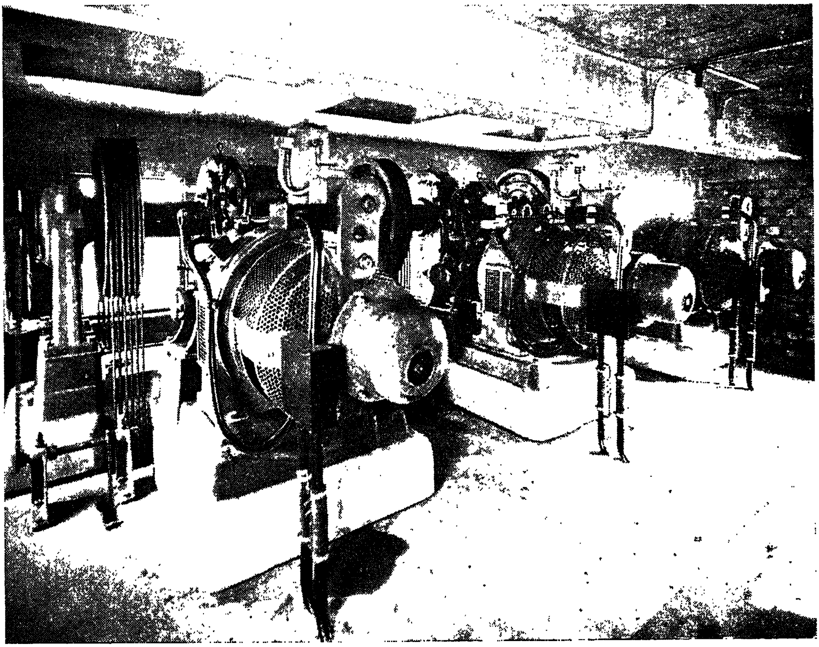


FIG. 54. INSTALLATION OF A.C. COMMUTATOR MOTORS FOR THREE LIFTS

(Motors: B.T.-H.; Lifts: Waygood-Otis)

motor in order to obtain the necessary high starting torque, after which, the brushes are lifted by a centrifugal governor, and the commutator short-circuited, the motor finally running as a squirrel-cage induction motor.

The "Type C.K.S." repulsion-induction motor manufactured by the British Thomson-Houston Co., however, and to which the following description refers, has no centrifugally operated commutator short-circuiting and brush-lifting device, and the motor is, therefore, not so complicated as the usual type mentioned above. The rotor laminations have two concentric sets of slots joined by narrow radial slits in which are placed thin metallic strips. These slots contain two distinct windings; a

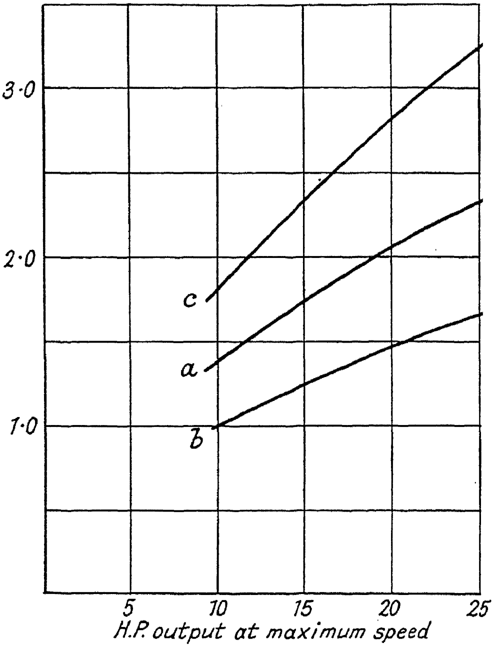


FIG. 55. CURVES SHOWING COMPARATIVE COSTS OF VARIOUS TYPES OF CHANGE SPEED A.C. MOTORS

(a) Change-pole slip-ring motors
(b) Change-pole short-circuited rotor motors
(c) Commutator motors

(*Metropolitan Vickers Gazette*)

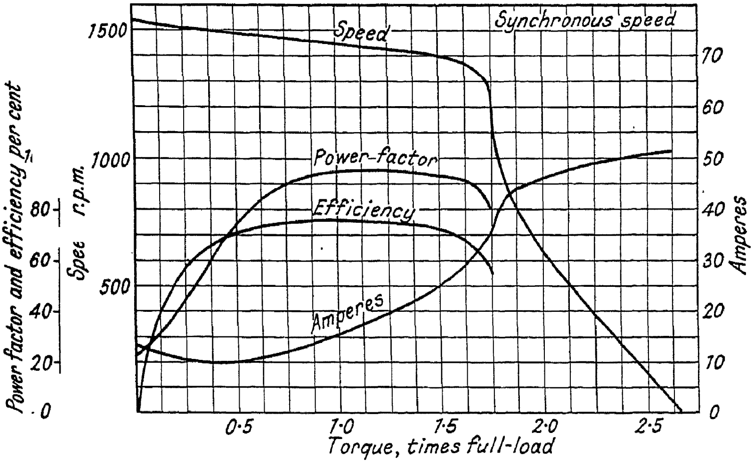


FIG. 56. TYPICAL CHARACTERISTIC CURVES OF REPULSION-INDUCTION MOTOR

Type CKS 3 816, 3 h.p., 1 450 r.p.m., 4-pole, 210-volt, 50-cycle, single-phase

(*B.T.-H.*)

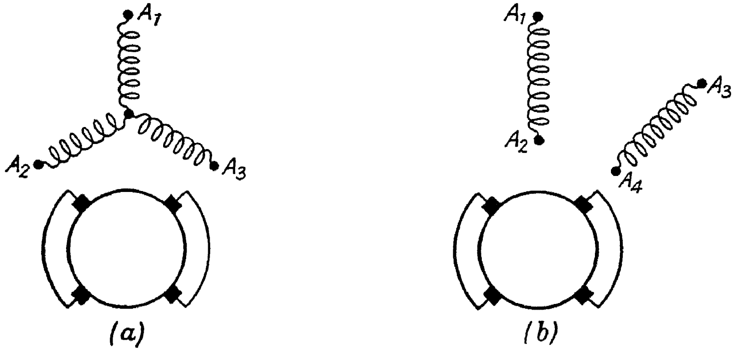


FIG. 56A. WINDINGS OF SINGLE-PHASE REPULSION-INDUCTION MOTOR

(*a*) For motors up to 3 h.p.
For one rotation connect A_1 and A_2 to line
For opposite rotation connect A_1 and A_3 to line
(*b*) For motors above 3 h.p.
For one rotation join A_2 to A_3 and connect A_1 and A_4 to line
For opposite rotation join A_2 to A_4 and join A_1 and A_3 to line

(*B.T.-H.*)

commutator winding (similar to a d.c. armature winding) in the outer slots and a cast aluminium squirrel-cage winding in the inner slots. The stator is wound with a simple single-phase winding.

During the starting and accelerating periods, the flux produced by the stator winding links with the outer winding only, due to the high reactance of the squirrel-cage, and the motor acts as a repulsion motor giving a high starting torque. As the motor accelerates, the reactance of the squirrel-cage decreases, so that more and more of the flux links with this winding and both windings now assist in the acceleration, thereby producing a large torque. On light loads, i.e. at speeds above the synchronous speed, the squirrel-cage exerts a braking torque and prevents the speed increasing to more than 2 per cent or 3 per cent above the synchronous speed.

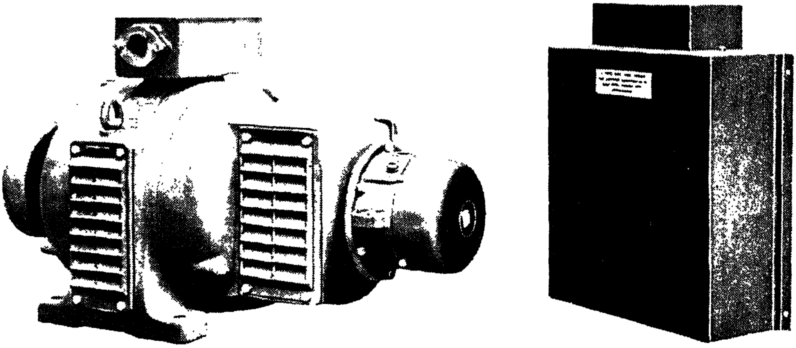

(a) (b)

FIG. 57. CAPACITOR TYPE SINGLE-PHASE LIFT MOTOR
(a) Motor (b) Condensers
(*B.T.-H.*)

The motor is started by switching direct on the lines, the starting current being approximately 3½ times the full load current, whilst twice the full load torque is developed. The starting current may, if required, be reduced by inserting an external resistance in the line circuit, when the torque developed will be reduced as the square of the starting current. Typical characteristic curves of this motor are shown in Fig. 56, and the arrangements of the motor windings in Fig. 56A.

With high efficiency gearing and an overhauling load, it is possible for the torque developed to be insufficient to effect reversal of rotation of the motor in the event of the car switch being instantly reversed. A time delay is therefore provided in conjunction with the main reversing contactor in order to delay the reversal by approximately 0·5 sec., to enable the brake to operate and reduce the motor speed. The motor will then develop the necessary reverse torque.

CAPACITOR MOTORS, During recent years the cost of condensers has been reduced and their reliability increased, and this has made practicable the use of capacitor motors for single-phase lifts. This motor is quieter than the repulsion-induction motor and may be of either the squirrel-cage or slip-ring type, the latter being employed for the larger sizes.

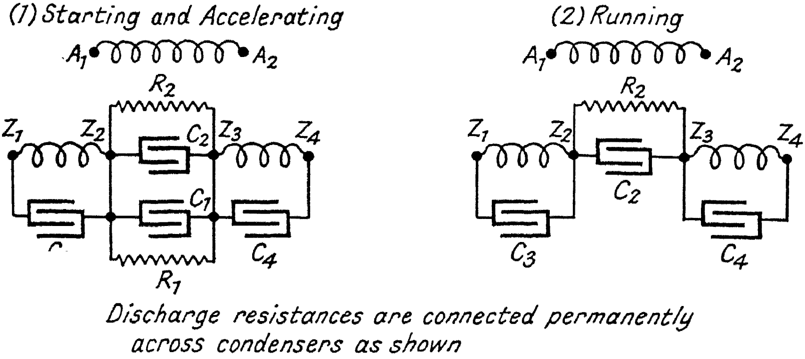
Electrically, these motors are, in effect, of the two-phase induction type, but operate on a single-phase supply, this being accomplished by the use of condensers which are housed in a separate metal capacitor unit as shown in Fig. 57. The stator has two windings; a main and an auxiliary winding displaced electrically by 90°, the condensers being connected to the latter winding. To obtain the high starting torque required for lift service and to ensure quiet running, the value of the capacitance at starting must considerably exceed that at full speed, and the effective capacitance must therefore be reduced as the motor speed increases. This is accomplished automatically by a centrifugal switch which operates at a predetermined speed, and as the motor slows down the switch resets ready for the next start.

The starting current of the squirrel-cage type is 3½ times full load current. The connexions for starting, acceleration, and running are shown in Fig. 58.

The slip-ring type has a lower starting current (2¼ times full load current) for an equivalent torque than the squirrel-cage type, and is used when the supply authority imposes starting current limitations. The condenser and winding connexions are shown in Fig. 59.

Another method of obtaining a lift drive from a single-phase supply is to employ a rectifier and use a d.c. motor. Except when the latest type grid-controlled rectifiers are used, however, this method has the disadvantage that dynamic braking is not possible unless some other form of rotating machinery is also being supplied by the rectifier, and will thus allow the lift motor to function as a generator. On account of this, some authorities limit the use of rectifiers to short-travel lifts.

Motors for Car Speeds between 120 ft. per min. and 350 ft. per min. Two separate speeds from a single-phase supply presents rather a difficult problem where only a single motor is to be used. The single-phase shunt-wound commutator motor,* however, is capable of fulfilling this requirement and giving the necessary high starting torque with low starting current. Advantage is taken of the property of this motor of providing speeds above and below the synchronous speed, these being used for running and landing respectively. The two speeds, as well as power factor correction, are obtained by the aid of a small transformer which injects a pressure into the brushes. In the lift motor described, the synchronous speed is 800 r.p.m., and this is raised to 1 000 r.p.m., corresponding to a car speed of 200 ft. per min., and lowered to 500 r.p.m., which provides a landing speed of 100 ft. per min.


(1) Starting and Accelerating

(2) Running

Discharge resistances are connected permanently across condensers as shown

FIG. 58. CONNEXIONS OF SINGLE-SPEED SQUIRREL-CAGE CAPACITOR LIFT MOTOR

A_1, A_2	Main winding	C_1	Starting condenser
Z_1, Z_2 Z_3, Z_4	Auxiliary winding	C_2, C_3, C_4	Running condensers
		R_1, R_2	Discharge resistances

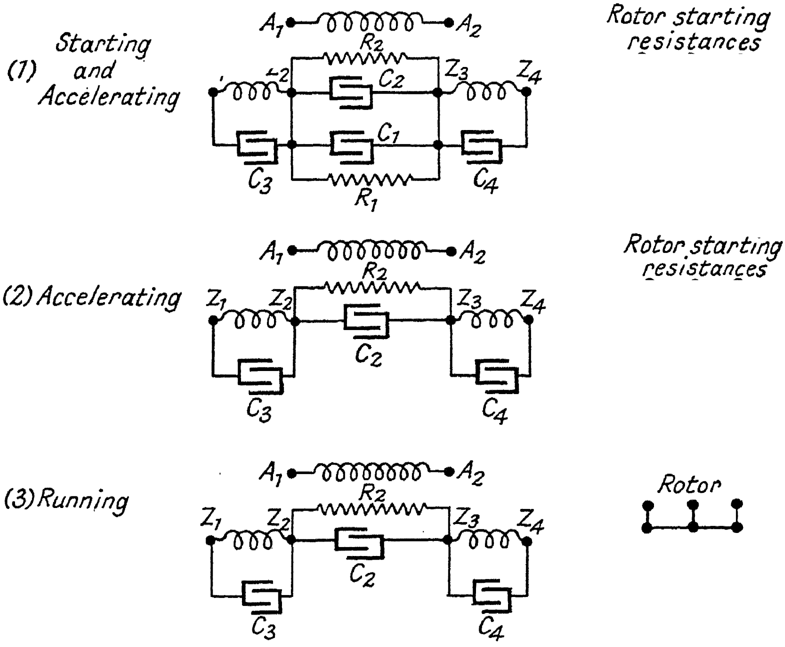
For one rotation connect Z_1 to A_1, and Z_4 to A_2; and for other rotation connect Z_4 to A_1, and Z_1 to A_2 and connect A_1 to line 1 and A_2 to line 2.

(*B.T.-H.*)

---

* "High Speed Lifts on Single-phase Supply," by R. E. Hopkins: *Electrical Review*, 11th January, 1929.

The motor connexions during the three stages of starting, running, and stopping whilst travelling in both directions are shown in Fig. 60. With connexions as at (*a*), the motor develops a high starting torque and accelerates to a speed of 800 r.p.m.



Discharge resistances should be connected permanently across condensers as shown

FIG. 59. CONNEXIONS OF SINGLE-SPEED SLIP-RING CAPACITOR LIFT MOTOR

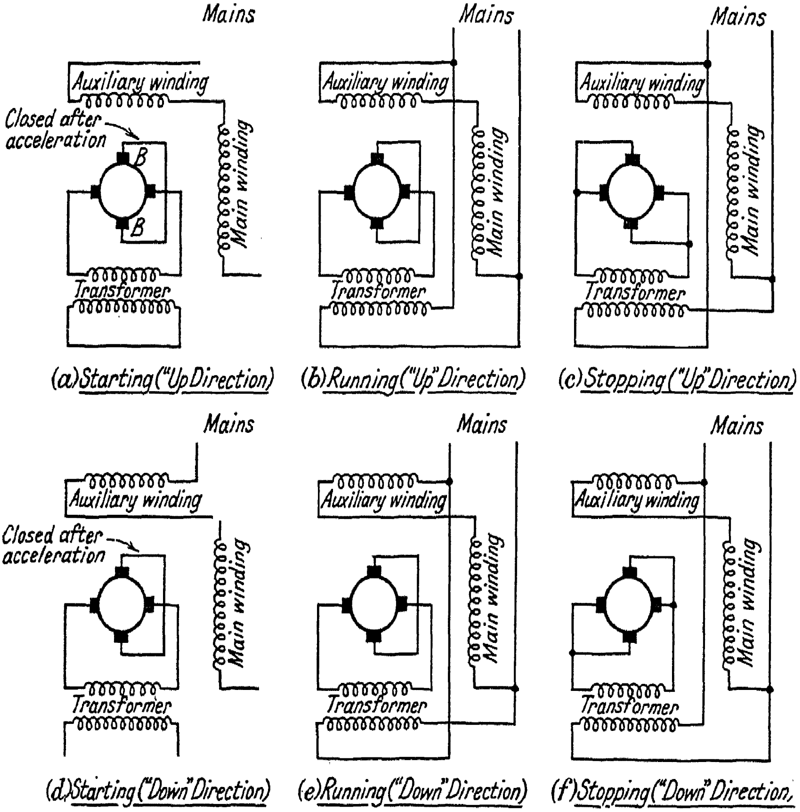
A_1, A_2	Main winding	C_1	Starting condenser
Z_1, Z_2 Z_3, Z_4	Auxiliary winding	C_2, C_3, C_4	Running condensers
		R_1, R_2	Discharge resistances

For one rotation connect Z_1 to A_1 and Z_4 to A_2; and for other rotation connect Z_4 to A_1 and Z_1 to A_2 and connect A_1 to line 1 and A_2 to line 2

(*B.T.-H.*)

When acceleration is complete, the brushes *BB* are short-circuited. Acceleration to a speed of 1 000 r.p.m. is effected by connexions (*b*), the transformer providing the hyper-synchronous speed and the high power factor to give a low current consumption. Connexions (*c*) give deceleration to

500 r.p.m. with the same transformer but with the connexions reversed, to reverse the sign of the impressed rotor voltage. The wiring for the down direction is shown at (*d*), (*e*), and (*f*).



(*a*) Starting ("Up Direction) (*b*) Running ("Up" Direction) (*c*) Stopping ("Up" Direction)

(*d*) Starting ("Down" Direction) (*e*) Running ("Down" Direction) (*f*) Stopping ("Down" Direction,

FIG. 60. TWO-SPEED SINGLE-PHASE MOTOR

Motors for Car Speeds above 350 ft. per min. The gearless d.c. machine with a motor generator set, the motor being wound for single-phase working, is the best practice.

CHAPTER VI

VARIABLE VOLTAGE EQUIPMENT

THE variable voltage or Ward Leonard method is the best for varying the speed of gearless motors, but it is also successfully employed with high grade geared d.c. machines. The results obtained are far better than those given by rheostatic methods, in which series and diverting resistances are used.

A motor generator set is employed, the generator of which supplies voltage to the lift d.c. motor; the motor of the set receiving its supply from the mains. The set motor is a standard, constant speed machine, the type used depending upon the characteristics of the power supply available, whilst the generator is usually a shunt-wound d.c. machine, having its armature permanently connected (electrically) to the armature of the lift motor. When the mains supply is a.c., a small exciter is installed in addition to the motor generator set to provide the direct current for the lift motor and generator fields and magnets of the brake and control gear. Automatic levelling may be performed without the use of an auxiliary machine, and in these cases the generator is provided with an additional shunt field which supplies the low voltage necessary to drive the lift motor at the slow levelling speed.

Since the lift motor receives its supply from the generator it is seen that the speed and direction of the car travel vary with the magnitude and polarity of the generator voltage, these in turn depending upon the strength and direction of the generator field. Acceleration of the car is obtained by strengthening the generator field, the lift being brought up to its final full speed by weakening the lift motor field. Retardation is effected by reversing these operations.

The advantages of this type of control are—

(i) The acceleration and retardation are smoother than that which is obtainable with any other form of control, as the generator voltage is free from any sudden changes.

(ii) It may be used on any supply by employing a suitable driving motor.

(iii) The controller is comparatively simple and its contactors need only be constructed to handle small currents of the order of a few amperes, as opposed to the large contactors handling the full power as in the case of rheostatic control.

(iv) The maintenance and running costs are relatively low since the controller, usually the chief source of trouble, is simple, and there are no rheostatic losses when accelerating, retarding, or running at reduced speeds.

When car switch control is employed the motor generator set is started by pressing a button fitted in the car, and the attendant can therefore shut down the set during slack periods. With automatic control, however, an automatic shut-down device is often incorporated, and is adjusted so that if no calls are received for, say, ten minutes, the motor generator set is automatically stopped, and motor generator standby losses are therefore eliminated. When a call is received the set is automatically started, but the car will not start until the motor generator full speed has been attained.

Speed Regulation. The speed/load characteristic of the set as a whole is a falling one and some method is invariably adopted to raise the characteristic, i.e. to make the speed independent of car load variations. To provide accurate floor levelling, however, it is desirable in practice to arrange that the motor speed when lifting full load is slightly higher than the no-load speed, and this involves a rising characteristic. This artificial variation is introduced so that the amount of brake slip when lifting full load is practically the same as when lowering full load (see Chapter XIII).

Several methods have been used for improving the regulation, one of which is the over-compounding of the generator field to give an increase in generator voltage when operating against full load. When the load is overhauling, however, and the lift motor functions as a generator, the current in the series winding is reversed and opposes the current in the shunt field. The series winding, being designed primarily for use when the generator is supplying current to the winding motor under full load conditions, is therefore generally of such a strength that it is possible for the series winding to overpower the shunt field. This is guarded against by incorporating some device which, when the lift motor operates as a generator, automatically and gradually shunts the current flowing through the series winding and thus prevents overpowering of the shunt field. The controller for this scheme is rather complicated and must be capable of handling heavy currents.

Another method, and one which has proved satisfactory, makes use of a separate small booster, whose armature is connected in series with the generator shunt field, and its field in series with the generator armature, as in the diagram in Fig. 61. Hence, as the generator load increases, the speed of the lift motor tends to decrease, but the booster generates a correspondingly increased e.m.f., thus boosting the generator shunt field and holding up the lift motor speed. With an overhauling load, the generator armature current and booster field current are reversed, and thus the voltage generated by the booster is also reversed. The resultant generator field and output voltage are therefore reduced in values, and this counteracts the tendency of the overhauling load to produce an increase of speed. Fig. 62 is an illustration of a variable voltage set with driving motor, generator, booster, and exciter, the gearless motor for this set being shown in Fig. 63.

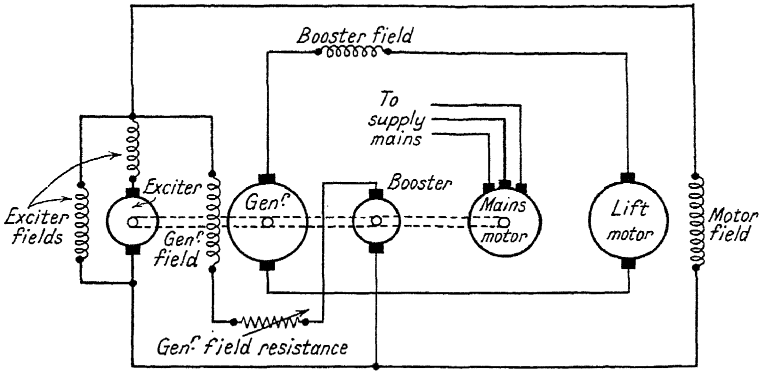


FIG. 61. VARIABLE VOLTAGE SET WITH BOOSTER AND EXCITER

A modification of the above method consists of a motor generator set, the generator of which has a common armature winding specially elongated to embrace the two separate (generator and booster) field systems, and one commutator together with its brush gear is therefore eliminated. The

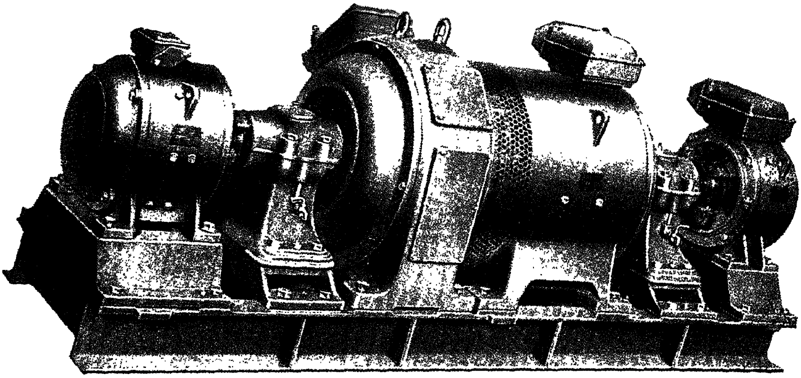


FIG. 62. VARIABLE VOLTAGE SET
(*J. & E. Hall, Ltd.*)

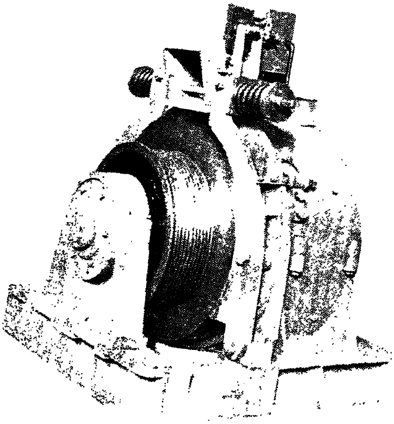


FIG. 63. GEARLESS LIFT MOTOR
(*J. & E. Hall, Ltd.*)

principle of this arrangement is shown in Fig. 64. The generator field system has shunt and interpole windings but no series windings. Demagnetizing windings are superimposed on the shunt field poles, the former being only in use during stopping and whilst the lift is stationary. The booster field system has three sets of series windings and by this means four combinations of windings can be obtained to give various values of boost. The booster field system also has a demagnetizing winding in series with that on the generator field, so that the two always function simultaneously when brought into action. A controller diagram which incorporates this set is shown in Fig. 186. During operation the current generated in the armature passes through the booster field on its way to the lift motor winding. If the lift machine is "motoring," then the loop current passing through the booster field winding generates a voltage in the armature which is added to the generator voltage. This ensures a rising voltage on the loop circuit with increase in "motoring" load and is so arranged to give a flat or slightly rising speed characteristic. If the lifting machine is "generating," then the generated current passing through the booster field winding generates a voltage opposed to the generator voltage already present. This ensures a decreasing voltage on the loop circuit with increase in generating load. It will be noted that there is no interaction between the two field systems but simply an

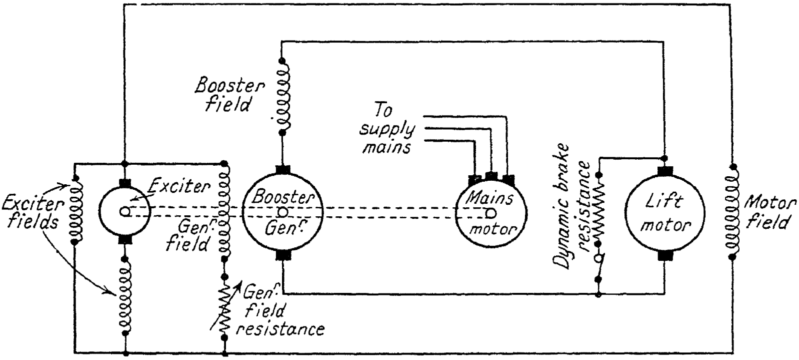


FIG. 64. VARIABLE VOLTAGE SET WITH GENERATOR AND SELF-CONTAINED BOOSTER

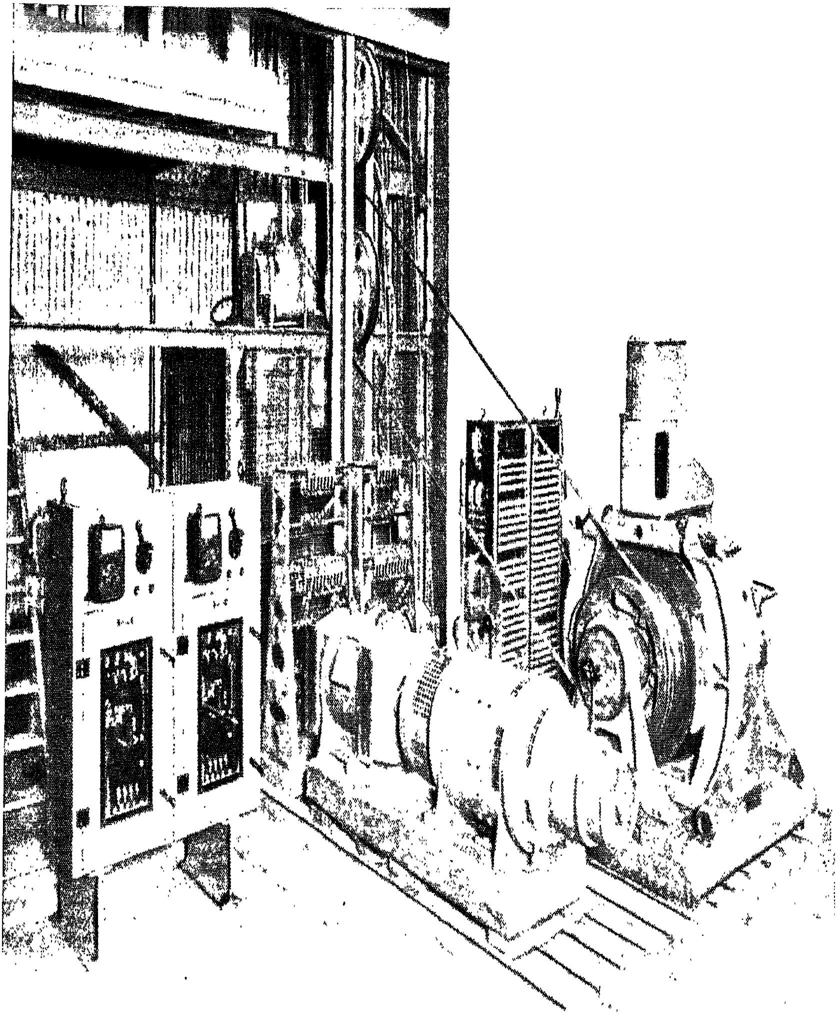


Fig. 65. Variable Voltage Set with Generator and Self-contained Booster

(Wm. Wadsworth & Sons)

arithmetical addition or subtraction of volts to or from the generator volts as the load changes in magnitude and characteristic. A variable voltage set of this type together with gearless driving motor and controller is shown in Fig. 65.

CHAPTER VII

BRAKES

It is important that a lift brake shall be of good design and that the number of wearing parts shall be kept to a minimum in order that it may maintain its adjustment for long periods without attention. Accurate and reasonably constant brake adjustments are essential, as a badly adjusted brake can be responsible for inaccurate floor levelling and consequent "inching," accompanied by greater wear on the controller contacts and an increase in the energy consumption.

The most common form of lift brake is constructed on the electromagnetic principle, and in the majority of cases is situated between the motor and the gearbox, i.e. on the high-speed side where it has the greatest mechanical advantage. In a gearless lift the brake is fitted between the motor and the driving sheave. So that the brake may be capable of sustaining the car when the motor armature is withdrawn for repairs, the brake drum is fitted on the worm shaft side of the coupling. The shoes, usually in two parts, are lined with Ferodo or similar material and sometimes function as independent units in order that, in the event of a failure of one half, the other will be available for braking. Operation of the shoes is effected by spiral springs, and release by means of an electromagnet, the solenoid of which acts upon the brake shoes either directly or through a system of links. The disadvantage of links and pins is that small wear on the pins may result in a comparatively large amount of lost brake motion. In some forms, the electromagnet is placed below the shoes and the springs above, as in Fig. 66, whilst in others this arrangement is reversed, an example of which is seen in Fig. 67. In yet another type both solenoid and springs are placed above the shoes, as in the brake shown in Fig. 68. A brief description of Messrs. Marryat & Scott's brake seen in Fig. 67 will serve to illustrate the principle of operation and the method of adjustment of a well-designed brake. In the type shown, wear is possible only at the brake linings and the pins *A* and *B*, and as the radial

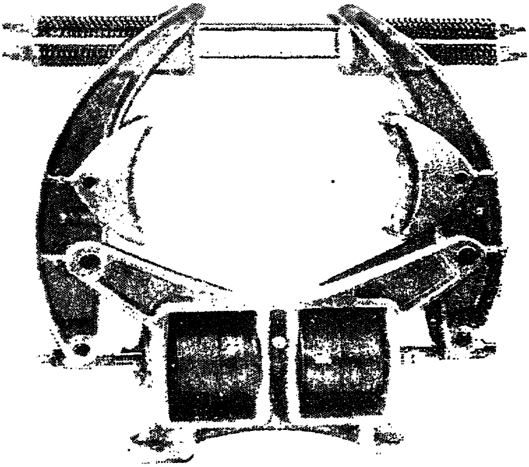


FIG. 66. ELECTROMAGNETIC BRAKE
(Electromagnet below and springs above)
(*Wm. Wadsworth & Sons*)

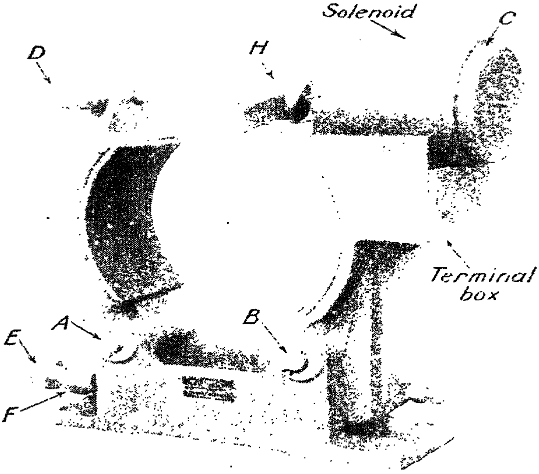


FIG. 67. D.C. LIFT BRAKE
(Electromagnet above and springs below)
(*Marryat & Scott*)

movement of the pins is less than 1° and the bearing surface $5\frac{1}{2}$ times the pin diameter, the wear on these pins is very small. Wear on the linings results in an increase of the air gap at *C* which is corrected by withdrawing the set screw *D* as required. The shoes are applied by a compression spring situated in the brake base-block and released by a solenoid acting directly upon the shoes. The strength of the spring and hence the force exerted by the shoes may be adjusted by the screw *E*. The adjustment for maximum torque is made at the works, after which a steel collar *F* is fitted to prevent further compression. If the maximum torque is not required, the adjusting stud can be screwed back. In the 12 in. size, which develops a torque of 300 lb. ft., the spring is 9 in. long, $1\frac{1}{2}$ in. diameter and the spring movement during operation is only $\frac{1}{64}$ in. The solenoid windings are totally enclosed and protected from dirt, damp, and mechanical damage. A hand release *H* is also provided and enables passengers to be released from the car by hand turning with the motor shaft crank handle provided, in the event of a fault occurring.

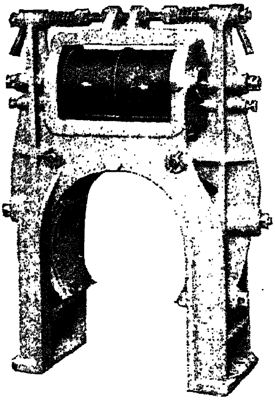


FIG. 68
ELECTROMAGNETIC BRAKE
(Electromagnet and springs above)
(*J. & E. Hall, Ltd.*)

A.C. versus D.C. Brakes. The principles of design and operation of an a.c. brake are somewhat different from those of a brake intended for use on d.c. In the cases of two-speed a.c. motors, and of d.c. motors, the mechanical brake is assisted by the dynamic braking action, but single-speed a.c. motors do not lend themselves to dynamic braking, and consequently the whole of the braking force must be supplied by the mechanical brake which must, therefore, be greater in size. Further, since the rotor of an a.c. machine is larger than that of a comparable d.c. machine, the brake in the former case must be still larger. The operation of a d.c. brake can be made very smooth by connecting a resistance in parallel with the coil, the resistance providing a path for the induced currents and allowing the flux variations to take place gradually. This resistance also prevents the puncturing of the insulation of the brake coil by any rise in pressure due to a supply interruption. It is not practicable, however, to use a parallel resistance with an a.c. brake, and the tendency is for the shoes to be applied more fiercely. A dashpot is often fitted to minimize the brake shock on application of the shoes. The magnet is, in addition, often immersed in oil so as to dissipate the heat developed in the coil and magnet. Two types of oil immersed a.c. brakes are illustrated in Figs. 69 and 70. Solid magnetic cores are employed in a d.c. brake, and laminated cores for a.c. brakes in order that the eddy-current losses in the latter type shall be kept to a minimum. Fig. 71 shows a contactor type a.c. brake with laminated core. Silence is another point in favour of the d.c. brake, although hum from a.c. brakes can be considerably reduced by employing copper loops in the faces of the magnet cores. The current induced in the loop causes the shaded pole flux to be reduced and to lag behind the main flux, and this results in a more even brake pull. Other differences between the two types of brakes are, that whilst the d.c. brake takes the same current regardless of position of the shoes, the a.c. brake takes a much larger current when the air gap is large than when it is small; and although the pull in the case of the a.c. magnet is nearly constant throughout the travel of the solenoid plunger, in a d.c. magnet the pull is approximately inversely proportional to the square of the air gap. On account of the difficulties associated with a.c. brakes some authorities

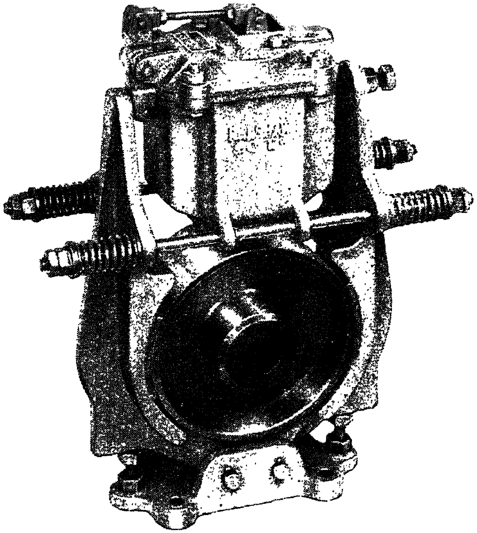


FIG. 69. OIL IMMERSED A.C. BRAKE
(R. J. Shaw & Co.)

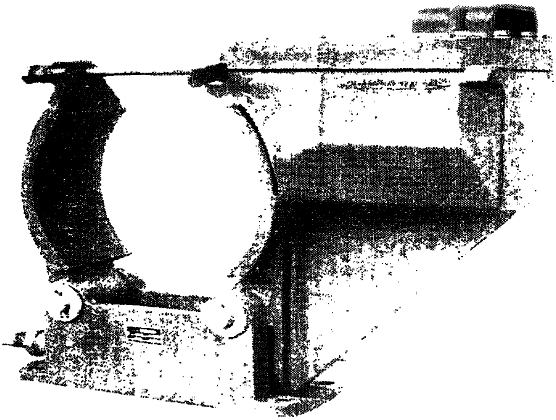


FIG. 70. OIL IMMERSED A.C. BRAKE
(*Marryat & Scott*)

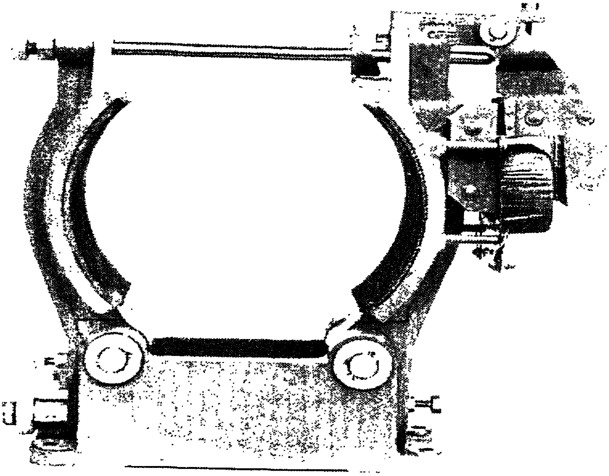


FIG. 71. CONTACTOR TYPE A.C. BRAKE
(*Marryat & Scott*)

prefer to install d.c. brakes regardless of the nature of the supply, and when this is a.c. the brake supply is obtained from a rectifier.

For gearless d.c. machines the brake must be of larger size because of the absence of gearing. So far as rotor kinetic energy is concerned, however, although the rotor is much larger, it runs at a considerably reduced speed. A brake for a gearless d.c. machine is illustrated in Fig. 72.

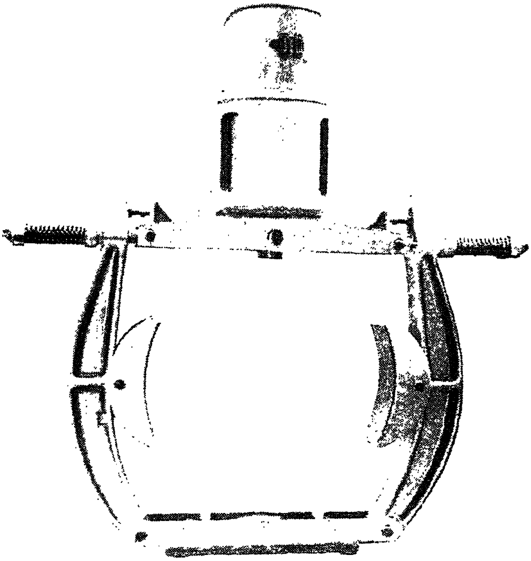


FIG. 72. GEARLESS MACHINE D.C. BRAKE
(*Wm. Wadsworth & Sons*)

Torque Motor Brakes. The brake shoes on a number of large a.c. lifts are released by a small torque motor of special design, 2- or 3-phase, and of the squirrel-cage type. The shoes are applied by means of springs, the action of which is damped by an air dashpot. The following brief description refers to Messrs. Waygood Otis' torque motor brake, a diagram of which is shown in Fig. 73. The type illustrated is for use on lifts not fitted with their micro-levelling motor. In order to release the brake, the motor makes a little under half a revolution, the motion being limited by a dashpot piston which is connected to the rotor spindle by means of a rack and pinion mechanism. The dashpot piston also serves as a weight to return the rotor to its original position when the current to the small torque motor is cut off. The rotary motion given by the motor is transformed into a straight line motion by means of two cams *B* and *C* attached to the rotor shaft projecting from each end of the motor. The working surfaces of these cams form, in effect, right- and left-hand screw threads which engage with and actuate ballbearing rollers attached to the roller arms *A*. Motion from the roller arms is transmitted to the brake levers by means of adjustable links D, so that when the rotor revolves, the brake shoes are lifted clear of the surface and the springs compressed.

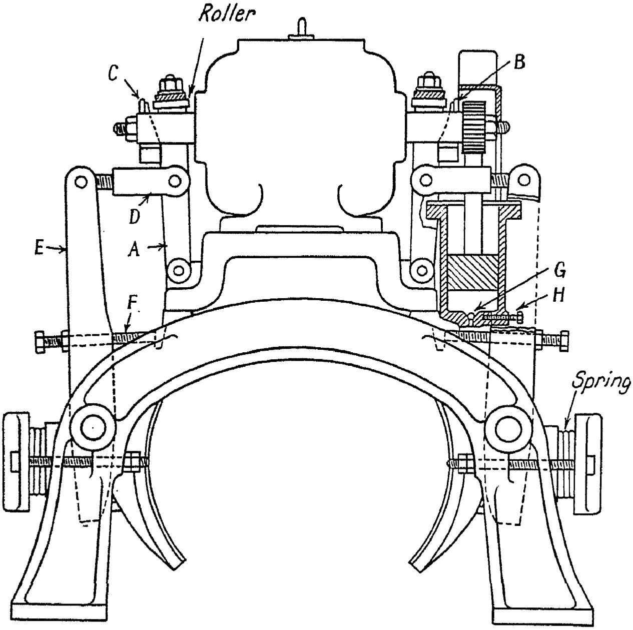


FIG. 73. TORQUE MOTOR BRAKE FOR POLYPHASE A.C. LIFT
(For machines without micro-levelling device)
(*Waygood Otis, Ltd.*)

When the supply is interrupted, the weighted piston, in conjunction with the pressure (due to the springs) of the rollers against the cams, causes the rotor to return to its original position and thus applies the brake; the return motion being checked by the dashpot. The rotor is allowed a small float in an axial direction to permit the brake cams and shoes to equalize, whilst screw stops *F* are provided for adjusting the arms *E*. The dashpot is fitted with two valves, a ball check valve *G* in the bottom and an air valve *H* in the side, the latter being provided with adjustment, so that by closing it the application of the shoes to the coupling is somewhat retarded, and by opening it the action is accelerated. This adjustment allows of the valve being set so as to permit the shoes to be applied to the brake coupling gradually, thus minimizing shock in the car. A "phantom" illustration of the complete winding machine is shown in Fig. 74.

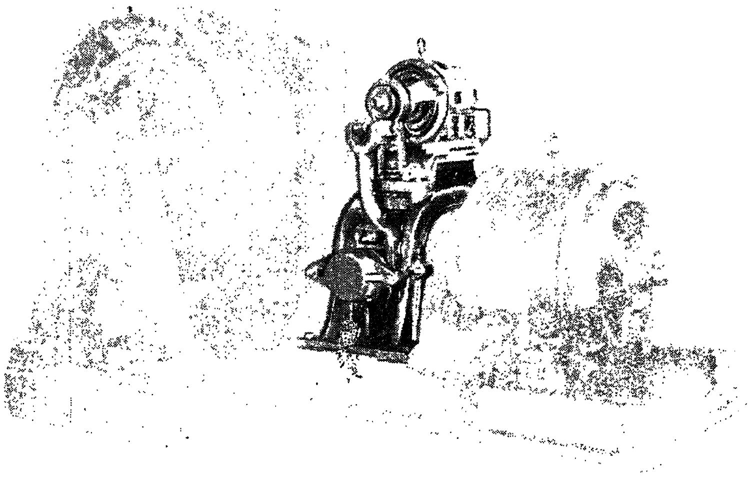


FIG. 74. TORQUE MOTOR BRAKE FITTED TO POLYPHASE A.C. LIFT MOTOR
(*Waygood Otis, Ltd.*)

In the case of the revolving brake used with Messrs. Waygood Otis' micro machines, the rotary motion of the torque motor, a diagram of which is shown in Fig. 75, is changed into a straight line motion by means of a cam *B*, mounted on the rotor shaft. The surface of the cam acts as an incline plane or screw thread, and through the ballbearing roller *C*, actuates the arm *A*. The motion of the arm is transmitted to the brake levers by the push rod *D* through the worm or spider of the micro-levelling machine. Hence as the rotor revolves, the shoes of the revolving brake are lifted clear of the brake drum. The set-screw *E* provides means of adjusting the position of the arm with regard to the push rod. *G* and *H* are the dashpot ball check valve and air valve respectively. The complete winding machine is illustrated in Chapter XIII, Fig. 169.

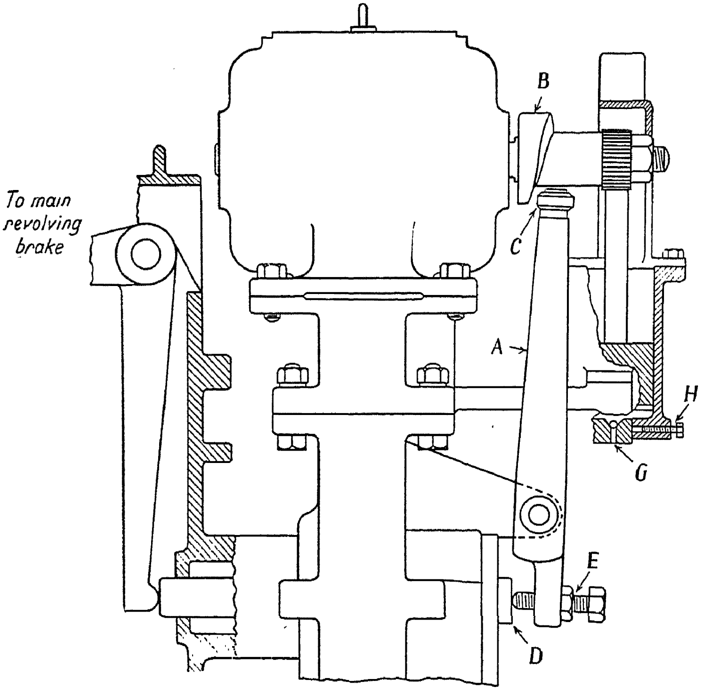


FIG. 75. TORQUE MOTOR BRAKE FOR POLYPHASE A.C. LIFT MOTOR
(For machines with micro-levelling device)
(*Waygood Otis, Ltd.*)

CHAPTER VIII

GEARING

If we assume that a typical lift has a lifting rope diameter of $\frac{5}{8}$ in., a sheave diameter of 50 rope diameters, i.e. 32 in., and a car speed of 200 ft. per min., then the speed of a suitable motor for a direct drive installation will be about 24 r.p.m. The slow-speed gearless motor, however, is only practicable for speeds above about 350 ft. per min., and for speeds slower than this a general purpose motor running at about 1 000 r.p.m. is used. Hence, with a motor of the latter type, it is necessary to use some form of gearing, the ratio of which, in the above case, should be 42 to 1. In practice, the gear ratios employed vary between about 20 to 1 and 60 to 1. Whilst it is not possible to use the gearless drive for slow car speeds it is also impracticable to employ gearing for speeds much in excess of 400 ft. per min. on account of difficulties in manufacture and in maintaining the thrust adjustment sufficiently accurate to ensure smooth operation. The type of gearing invariably adopted is the worm and worm-wheel, both members being totally enclosed in an oil-tight gearcase, typical examples of which are shown in Figs. 76 and 77. The worm may be either above or below the wheel and there are probably

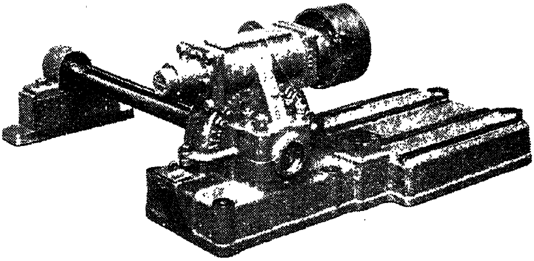


Fig. 76. Lift Gearbox
(*Marryat & Scott*)

as many of one type in use as the other. The former is termed the *over-type* gear, and the latter the *under-type*, each having its advantages. Over- and under-type geared machines are shown in Figs. 78 and 79 respectively. Advantages claimed for the over-type are that the low-speed load carrying shaft is lower down on the bedplate, the worm which suffers the most wear is capable of easy inspection, and it is not so difficult to maintain oil-tight joints in the gear casing. With the under-type gear, any wear in the main bearings allows the wheel to drop into closer mesh with the worm instead of drawing the gears apart, and, in addition, the lubrication is probably more complete, since the worm is always immersed in oil. Although, in the over-type gear, the worm is not immersed in oil, sufficient oil to provide ample lubrication is carried upwards by the worm-wheel teeth. The oil is thrown from the wheel and cooled during its passage down the gear case and back to the reservoir. The design of both types should be such that the temperature rise of the oil in the sump never exceeds 100° F. The worm-wheel is forced on to its shaft by hydraulic pressure and fixed

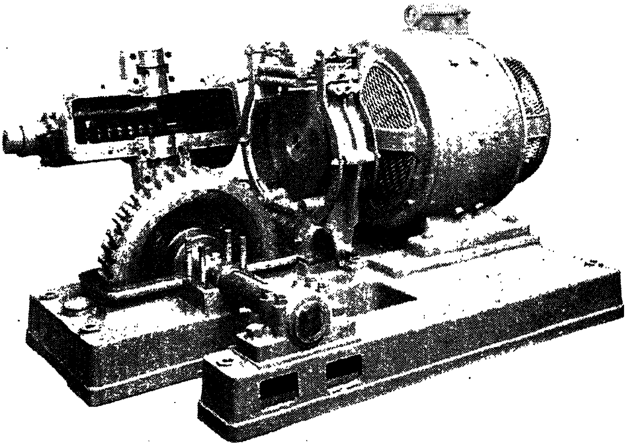


Fig. 77. Lift Gearing
(Worm and cover raised)
(*Marryat & Scott*)

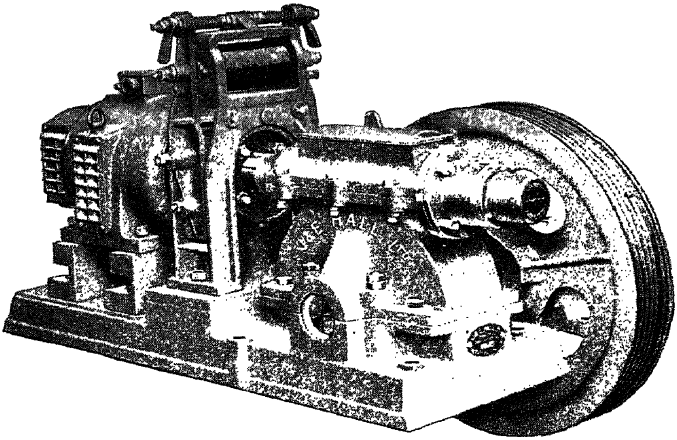


FIG. 78. OVER-TYPE GEARED MACHINE
(*J. & E. Hall, Ltd.*)

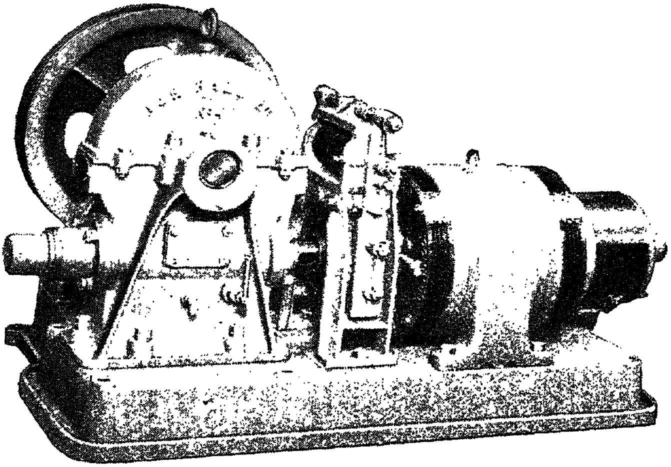


FIG. 79. UNDER-TYPE GEARED MACHINE
(*J. & E. Hall, Ltd.*)

by two keys at right angles to each other as in Fig. 80, which depicts a worm, wheel, and double thrust race. Alternatively, the wheel may be bolted to one flange of a worm and sheave centre, the other flange being bolted to the sheave. The combined centre is pressed on to its shaft and the latter method therefore obviates the use of keys. The worm shaft and the motor armature shaft are each secured to the brake drum by a key.

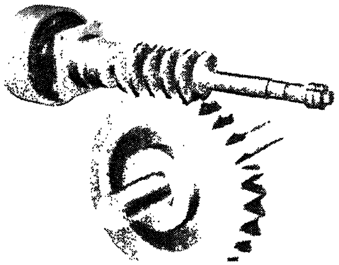


FIG. 80. WORM GEAR AND DOUBLE THRUST RACE
(*Marryat & Scott*)

For a worm and worm-wheel drive the most satisfactory materials for the two members are steel and phosphor bronze, and these are used for the worm and worm-wheel of lift gearing. The worm is made of 5 per cent nickel steel or $3\frac{1}{2}$ per cent nickel chromium steel, forged solid with the shaft, polished and case hardened, whilst the worm-wheel is of solid phosphor bronze for small gears, but for the larger gears consists of a renewable phosphor bronze rim and a cast-iron centre. The rim is either shrunk and fixed by grub screws or bolted to the centre: an example of the latter method of fixing the worm-wheel rim being shown in Fig. 81. To ensure silent running, the gear teeth must be accurately hobbed. As a safety precaution, the angle of lead of the worm is frequently made small, with a view to obtaining irreversibility of the gear; and the danger of the lift "running away," in the event of a brake failure, is therefore minimized.

Irreversibility. This, perhaps, may be best understood by considering the following fundamental relations—

$$\text{Efficiency (worm driving)} = \tan \lambda / \tan (\lambda + \phi) \text{ where}$$

λ is the angle of lead of the worm and $\tan \phi$ is the coefficient of friction between the worm and wheel, corresponding to the rubbing speed employed. The coefficient of friction μ varies from 0·013 at 3 000 ft. per min. to 0·10 at 5 ft. per min. for phosphor bronze on steel.*

---

* B.S.S. No. 721, *Machine Cut Gears—Worm Gearing.*

The efficiency is a maximum when $\lambda = (45^\circ - \frac{1}{2}\phi)$ and a minimum when $\lambda = 0^\circ$ and $(90^\circ - \phi)$.

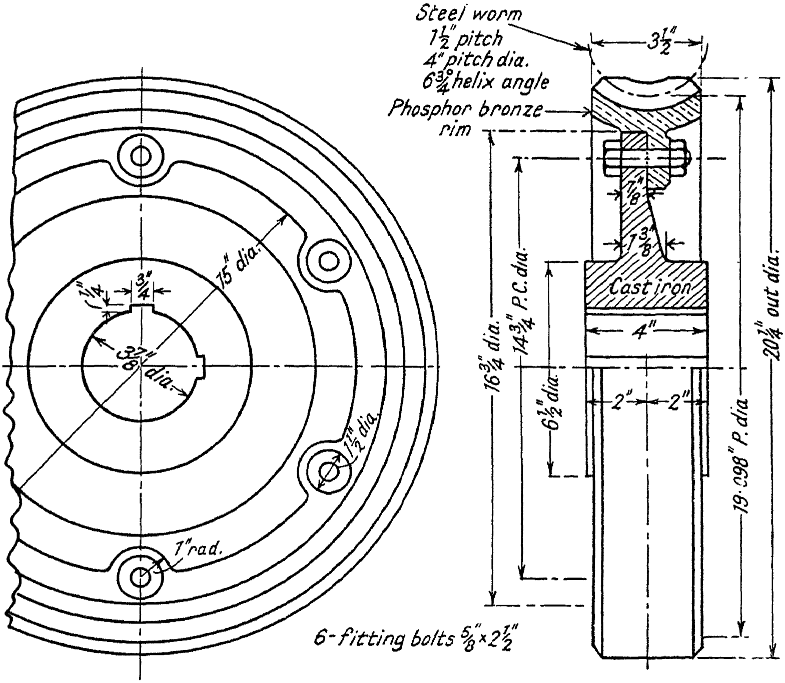


FIG. 81. PHOSPHOR BRONZE WORM-WHEEL
40 teeth, 1½ in. pitch
(*R. J. Shaw & Co.*)

Graphs showing the relations between efficiency and λ for various values of μ are shown in Fig. 82.

Reversed efficiency (wheel driving) $= \tan (\lambda - \phi)/\tan \lambda$.

The worm gear is irreversible if the reversed efficiency is zero or negative. This is the case when λ is equal to or less than the angle of friction ϕ. For irreversibility the efficiency cannot be more than 50 per cent, and from the graphs it will be seen that it may be considerably less. Further, it will be noted that λ must be small, particularly with high efficiency gearing.

The angle of friction, however, changes rapidly with the rubbing speed, and the static angle of friction may be reduced by external vibration. The design of irreversible worm gear is therefore always accompanied by an element of uncertainty, and it is recommended that to obtain complete security some form of brake be employed. High efficiency gearing is often used on modern lifts, and any degree of irreversibility of the gearing is thus sacrificed in favour of higher efficiency. The possibility of the lift "running away," however, is guarded against by fitting a handle in the car which, when pulled, operates the brake by means independent of the normal method of operation. Usually the handle releases a weight, which, in falling, forcibly applies the brake shoes to the drum and simultaneously opens the main limit switch.

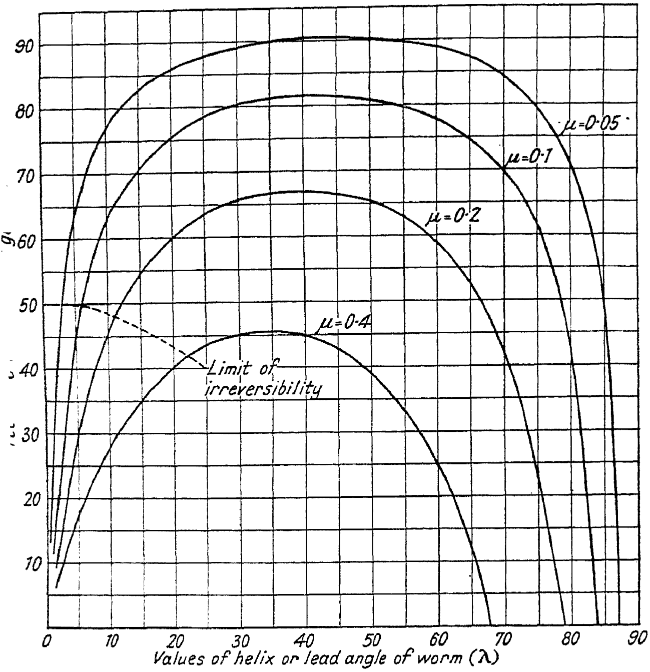


FIG. 82. GRAPHS SHOWING RELATION BETWEEN EFFICIENCY AND ANGLES OF LEAD OF WORM FOR VARIOUS VALUES OF μ

Thrust Races. The movement of the car up and down the well transmits thrusts in both directions of the worm axis and means must be provided to cater for these thrusts. Single ball thrust races are sometimes fitted at each end of the worm shaft, but more usually a double ball thrust as depicted in Fig. 83 is provided at the outer end of the shaft, the thrust race being capable of adjustment as wear takes place.

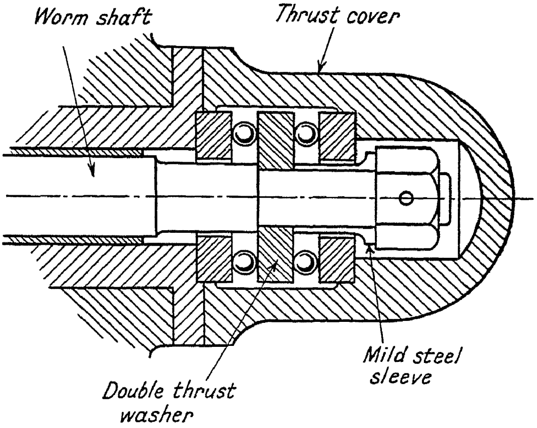


FIG. 83. DOUBLE BALL THRUST

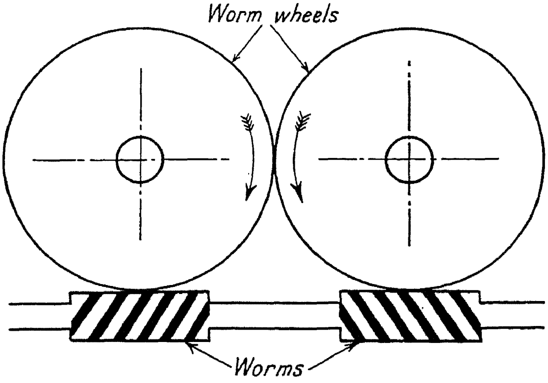


FIG. 84. TANDEM GEARING

Tandem Gearing. For heavy duty, tandem gearing, consisting of two worms and two wheels, is sometimes employed, the worms being respectively left- and right-handed. The worm-wheels are meshed together as well as the worms and wheels as in Fig. 84. With this type of gearing, the worm is subjected to two equal and opposite thrusts, and separate thrust bearings are therefore unnecessary.

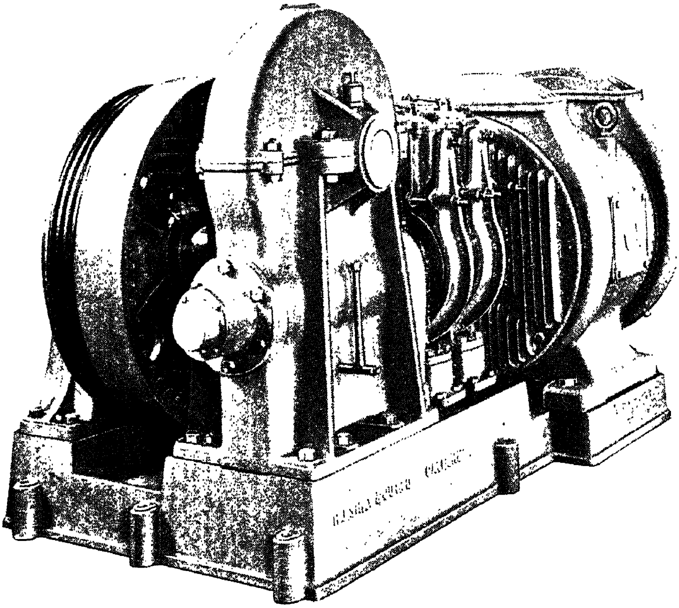


FIG. 85. DOUBLE-GEARED HEAVY DUTY LIFT MACHINE
(*R. J. Shaw & Co.*)

Spur Gearing. This is sometimes used, in addition to a worm reduction gear, for handling heavy loads at slow speeds. A double-geared machine of this type is shown in Fig. 85 and consists of the usual worm-geared machine with the addition of an internal spur reduction gearing. The machine shown is capable of lifting 3 tons at a speed of 100 ft. per min., and is fitted with twin oil-immersed brakes for operation from alternating current.

CHAPTER IX

CARS, COUNTERWEIGHTS, AND GUIDES

CARS

Passenger Cars. The number of passenger car designs is unlimited; the car can be made to almost any specification, the actual finish being usually left to the purchaser. There are a few items of design, however, which should be incorporated in all modern lift cars. The clear height should be at least 6 ft. 6 in., and usually is about 7 ft. 0 in. or even more. An alarm bell or a telephone should be provided, to enable a call for assistance to be made in case of breakdown or failure between floors. Where one lift only operates in a well, a hinged panel opening outwards should be fitted in the roof, as a means of exit in cases of emergency. If more than one car operates in a well, side exits are sometimes provided and these are either removable panels or doors opening inwards. These side exits enable the transference of passengers from one car to another. Means should also be provided in the roof adequately to ventilate the car, whilst artificial lighting is also necessary, and for this almost any form of fitting may be used. Very effective lighting can be obtained by means of tubular fittings at each of the four corners, or by laylights.

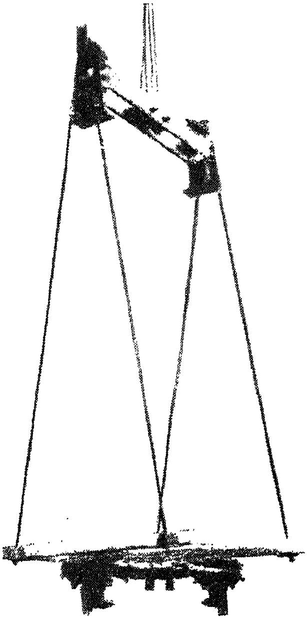


FIG. 86. CAR SLING
(Marryat & Scott)

Lift cars consist of two separate units, namely the *sling* and the *car*, the former being constructed of bolted or welded rolled steel angle or channel sections. A simple car sling is shown in Fig. 86. The side frames are built up of steel angles with gusset plates riveted to each corner, and vertical or diagonal stays to give extra strength and stiffness. The main suspension crosshead is fixed to the top of the frame, and to this is bolted the housing for the two spring-loaded top guide

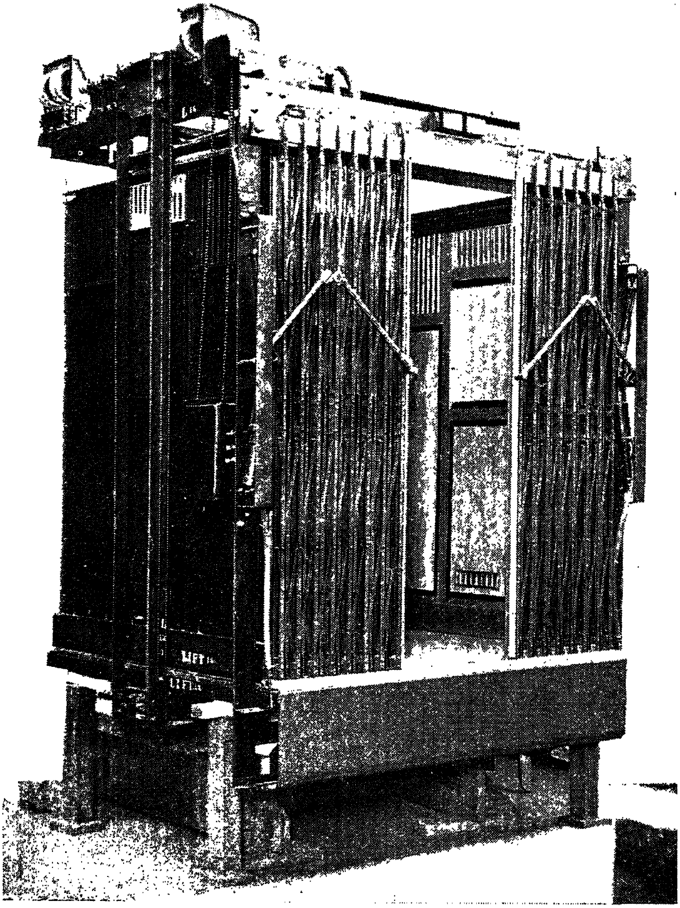


FIG. 87. PASSENGER CAR AND SLING WITH POWER-OPERATED GATES
Gates opened by compressed air and closed by springs
(*Wm. Wadsworth & Sons*)

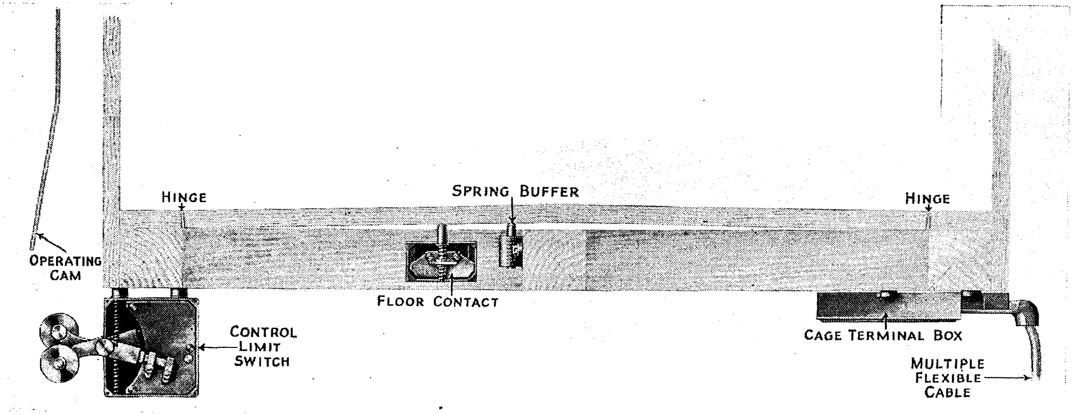


Fig. 88. Section of Passenger Car Floor showing Various Fittings
(*Etchells, Congdon & Muir*)

shoes, whilst the bottom sections carry the car safety gear and the remaining two bottom guide shoes. The lifting ropes may be attached to the top crosshead or they may pass over guide pulleys fixed to the crosshead and then round two opposite sides of the car and be secured underneath the car.

The car is rigidly fixed to the sling in such a manner that unequal loading on the floor cannot throw undue weight on the cabinet work. A typical car sling together with its car, the latter being fitted with pneumatically operated gates, is illustrated in Fig. 87. The floor is made of well-seasoned wood, usually maple, and frequently iron tongues are let in between the planks to afford extra strength. Linoleum, rubber, or parquet, finished in any design to blend with the remainder of the car, may be used as the floor covering. A switch is sometimes incorporated in the car floor; this switch, when operated

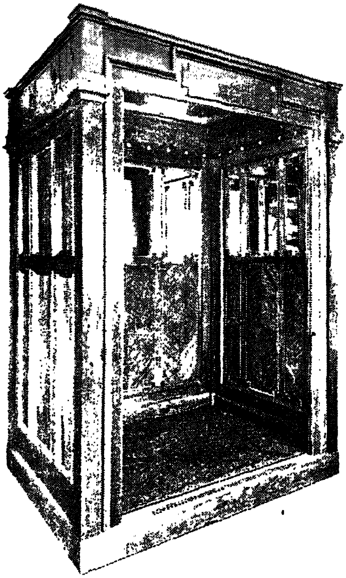


FIG. 89. PASSENGER CAR
(*Marryat & Scott*)

by the weight of a person standing on the floor, prevents interference from landings and ensures that the car gate must be closed when the lift is operated from the car, but need not be closed when called to a landing. A passenger car floor incorporating a floor switch and showing the terminal limit switch and the flexible cable terminal box is illustrated in Fig. 88. The car back and side framings are often of 1½ in. teak, oak, mahogany or walnut with panelling of about ¾ in. to match, whilst ornamental pilasters or corner posts may also be incorporated. Alternatively, a painted or enamelled finish or padded leather sides and back are sometimes adopted. A further

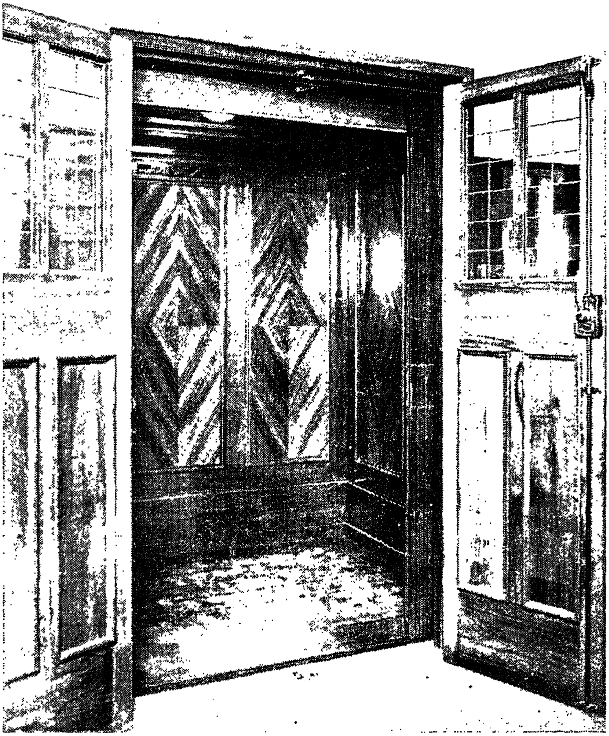


FIG. 90. PASSENGER CAR
(Marryat & Scott)

possible finish is laminated boards lined with rubber, the joints being covered with metal strips. The car top is usually domed and is of wood or stainless steel. Occasionally, seats, windows or mirrors are required, whilst a kicking plate about 9 in. deep and of bronze or stainless steel is frequently fitted. Figs. 89 and 90 show two cars finished in cross-banded walnut, and Fig. 91 a car in teak, designed for use in tropical climates: in addition to being well ventilated, this is fitted with an electric fan. A passenger car with power-operated gates is shown in Fig. 92. All-metal cars are becoming popular, and these too may be obtained with, or without, ornamental strips, and in

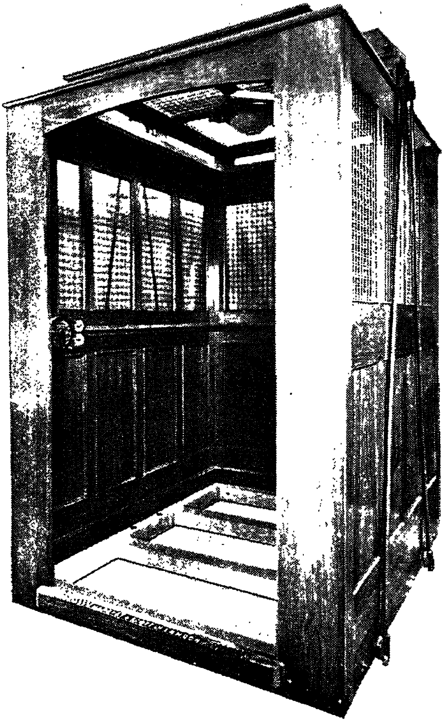


FIG. 91. CAR SUITABLE FOR TROPICAL CLIMATES
(Marryat & Scott)

almost any design and colour of lacquer finish. Examples of all metal cars are shown in Figs. 93 and 94.

Goods Cars. The sling is of similar construction to that adopted for passenger cars but the car itself is of much rougher construction. The floor is made of double planks at right angles, the top layer being made of well-seasoned maple planks about 5 in. wide and 2 in. thick, and the bottom layer of 2 in. deal,

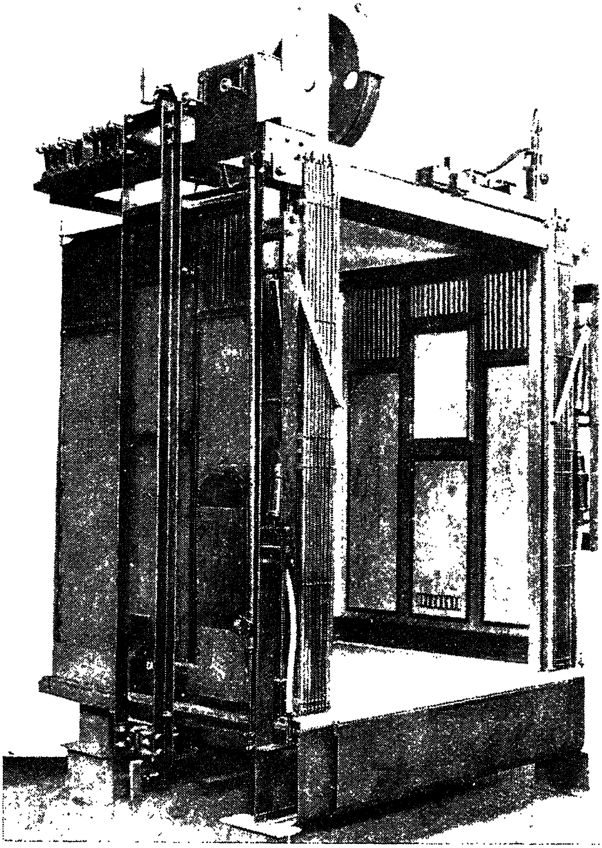


FIG. 92. PASSENGER CAR FOR GEARLESS LIFT
With corrective levelling switches, and pneumatically-operated mid-bar type gates
(*Wm. Wadsworth & Sons*)

whilst the sides, back, and top are of 1 in. tongued and grooved pitch pine. Wire mesh is sometimes used for the car top instead of wood. A typical goods car is shown in Fig. 95. The sides and back are often lined to a height of about 3 ft. with sheet steel $\frac{1}{8}$ in. thick. All-steel cars are frequently used for the transport of heavy or rough materials, the sides being

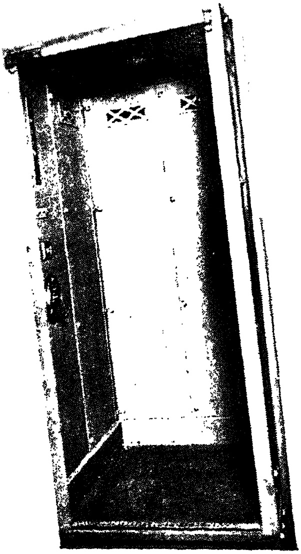


Fig. 93. All-metal Car
(Marryat & Scott)

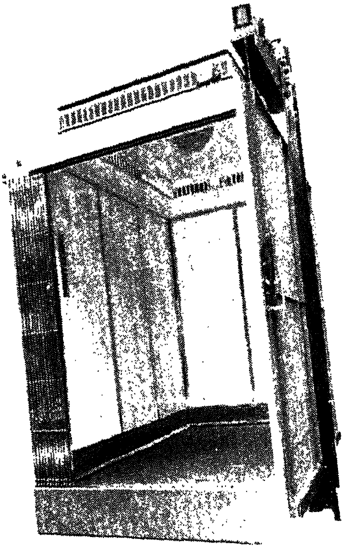


Fig. 94. All-metal Passenger Car with Retiring Cam
(Wm. Wadsworth & Sons)

constructed of sheet steel or expanded metal, and the floor of steel chequer plate. A general utility passenger-goods lift car with the car formed in sheet monel metal and with a monel metal close spaced bar screen, is shown in Fig. 96. The actual finish adopted for the car in any installation will depend upon the type of goods to be carried.

Car Flexible Cable. All electrical connexions to the car are made by means of a multi-core hanging flexible cable, one end of which is connected to a terminal box fitted under the car

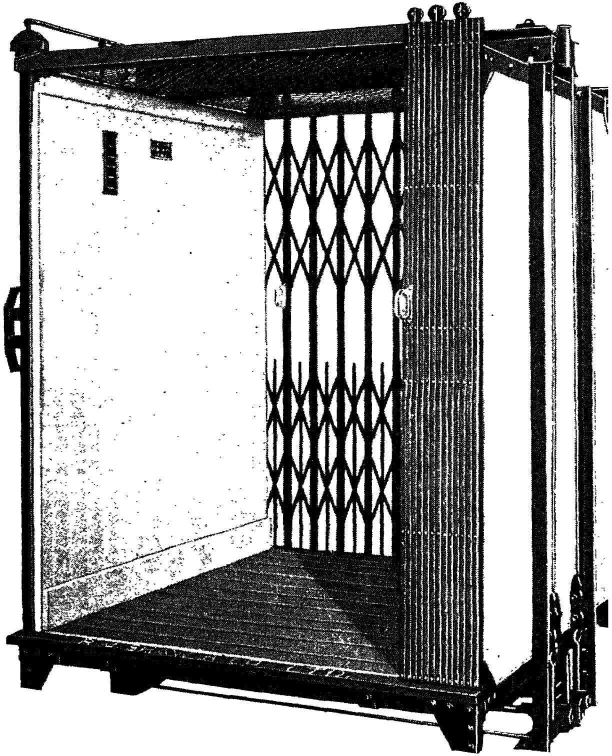


FIG. 95. GOODS CAR
R. J. Shaw & Co.)

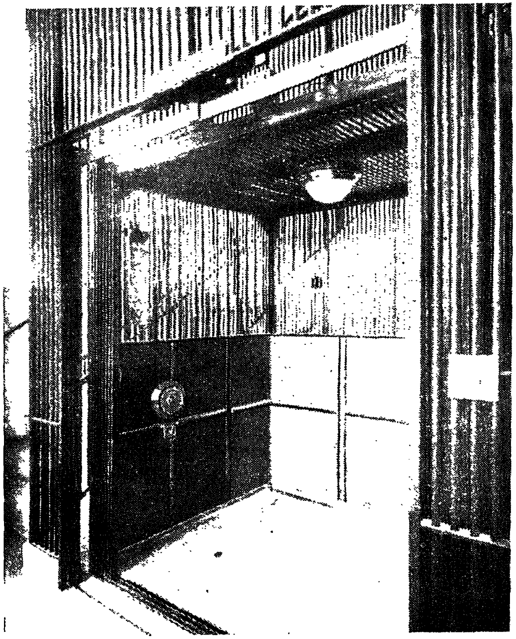


FIG. 96. ALL-METAL PASSENGER-GOODS CAR
(Marryat & Scott)

floor, the other end being attached to a terminal box fitted in the well at approximately the mid position. All car connexions from the controller are run to the well terminal box. The length of the flexible cable should be approximately equal to half the lift total travel plus 15 ft. so that the car may travel from end to end of the well without subjecting the cable to any strain.

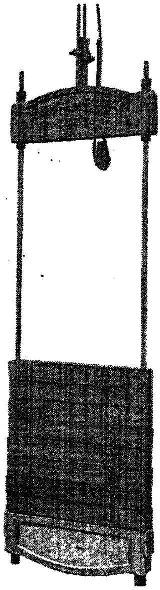


FIG. 97. COUNTERWEIGHT (*Marryat & Scott*)

COUNTERWEIGHTS

The object of the counterweight is to balance the weight of the car plus a predetermined proportion, usually 40 to 50 per cent, of the maximum car load, and thereby to reduce the size of the motor. Incidentally, the counterweight provides a certain measure of safety. The most usual construction consists of cast-iron sections firmly secured against movement by at least two steel tie rods having lock nuts at each end, and passing through each section. For heavy loads the sections are sometimes weighted with lead so as to reduce the size of the counterweight. The hoisting ropes may be secured to the counterweight top frame by eyebolts which allow of rope adjustment, by splices or clips. A counterweight minus its guide shoes is shown in Fig. 97, in which the ropes are anchored by a heart-shaped casting. Four spring-loaded shoes, similar to those for the car, are fitted to ensure that the counterweight will travel smoothly in its guides. Safety gear is often fitted and may be either of the types mentioned in Chapter XII.

CAR AND COUNTERWEIGHT GUIDES

Some form of guiding is necessary for both the car and counterweight so that they will travel in a uniformly vertical direction. In the most common arrangement, two guides are required for the car and two for the counterweight, but the actual number and the relative positions of the guides depend upon the landing openings required. Openings all on one side of the well permit of the simplest guide arrangement; the counterweight guides are fixed to the wall opposite the landings, and the car guides, one on each of the two remaining walls. In some instances it is necessary to cater for landing openings on opposite sides of the well, and in these cases a car guide is supported on each of the two remaining walls and both counterweight guides on one of these walls. Openings on adjacent sides or even on three sides are sometimes required, and this involves guiding the car diagonally at two of its corners, or alternatively at each of the four corners. In the case of this corner guiding, the car frame is cut away at the corners so as to provide fixings for the guide shoes. A three-point guiding is sometimes adopted for cars with adjacent openings, and in this arrangement two guides are placed, one at each corner of one side, with the third guide at the middle of the opposite side.

Material. In the past, both well-seasoned teak and rolled steel channel have been extensively used for car and counterweight guides, but modern practice favours either round steel or tee-section steel guides, except where the nature of the work carried on in the building renders steel unsuitable, due to acid fumes. In these cases specially prepared wooden guides are installed. Tee-section guides are the most up-to-date practice, and are now recommended for both car and counterweight on all lifts travelling at speeds in excess of 200 ft. per min. The advantages of tee-section guides are, that there is no tendency for the shoes to get out of place, as is possible with round steel guides; they afford a larger shoe bearing surface, and result in more even shoe wear. Further, this type of guide is sufficiently rigid to make the use of guide backings unnecessary.

Sizes. In practice round guides vary in size from 1½ in. to 2½ in. diameter, the actual size installed depending upon the car capacity. Suitable sizes of car guides for various capacity lifts are stated in the table on p. 118, the size of the corresponding counterweight guide being generally the size below that quoted in the table mentioned as required for the car guides.

A usual size for tee-section guides is 3½ in. (flange) × 2⅜ in.

Car Capacity (cwt.)	Diameter of Guide (in.)	Car Capacity (cwt.)	Diameter of Guide (in.)
5	1½	41–60	2¼
5–15	1¾	61–100	2½
16–40	2		

for both car and counterweight for capacities up to and including 15 cwt., and for car loadings above this, the car guides are increased to about 5 in. × 3¼ in. The guides are delivered in lengths of about 16 feet.

Fixing and Jointing. The method of fixing the guides depends upon the construction of the well and the relative positions of the car and counterweight guides, but the number of fixings should be such that the guides will not deflect more than ¼ in. under normal operation. In a staircase well or a self-contained steel structure the guides are fixed by plates and bolts with the additional provision of steel stringers if necessary. In a bricked well, the guides are secured either by Lewis bolts or by bolts passing through the brickwork and fastened on the outer sides by steel plates. The former method is frequently adopted for outside walls and the latter for inside walls. In either case, a sound fixing is necessary, and when Lewis bolts are employed they should be sunk in the wall at least 6 in. and firmly bedded. At their bottom ends, the guides are sunk into the well for about 9 in. and concreted.

Fig. 98 shows the method of fixing and jointing channel iron guides for counterweights. This form of guide is extensively used for counterweights of slow speed goods lifts. Each guide consists of two channels bolted together, the counterweight shoe travelling in the space formed by the web and two flanges of one of the channels. The various lengths, in each half of the guide, are arranged so that the joints are spaced at intervals of 4 ft., the jointing being carried out by four countersunk bolts passing through the web of each channel. The channels are, in addition, screwed to each other by single countersunk bolts at 4 ft. spacing. The iron strap is bolted to each guide at intervals of 4 ft. throughout the entire length of the guides. These straps are secured to each guide by a tapped bolt and a through bolt, the latter serving as the fixing to the well and

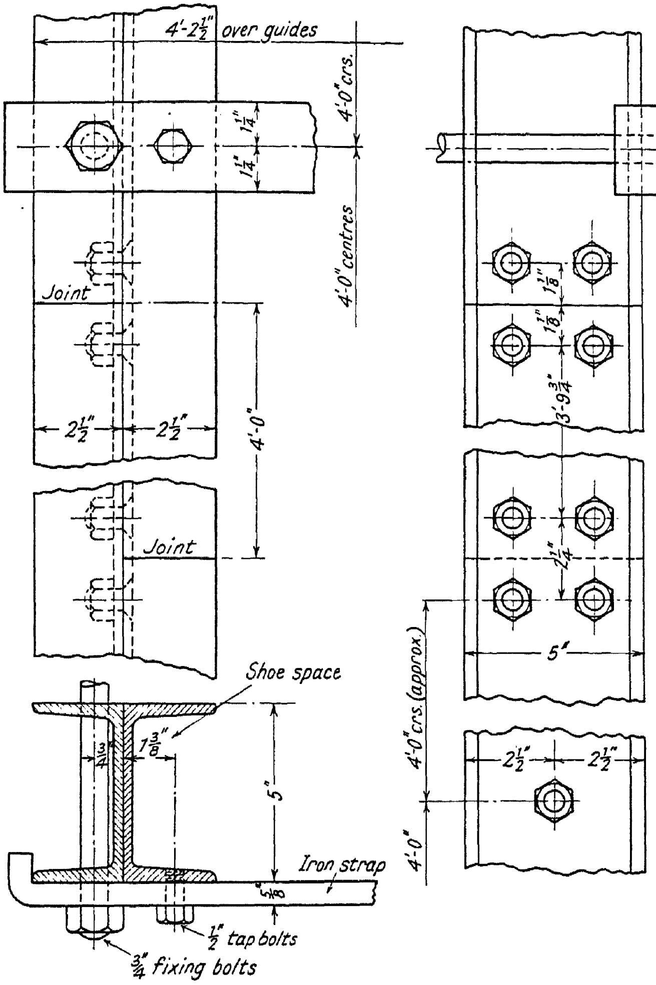


FIG HOD OF FIXING AND JO GUIDE

(R. J. Shaw &

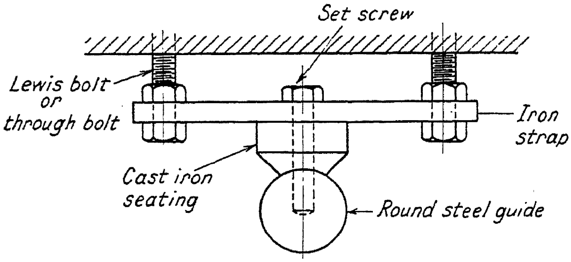


FIG. 99. ROUND GUIDE FIXINGS

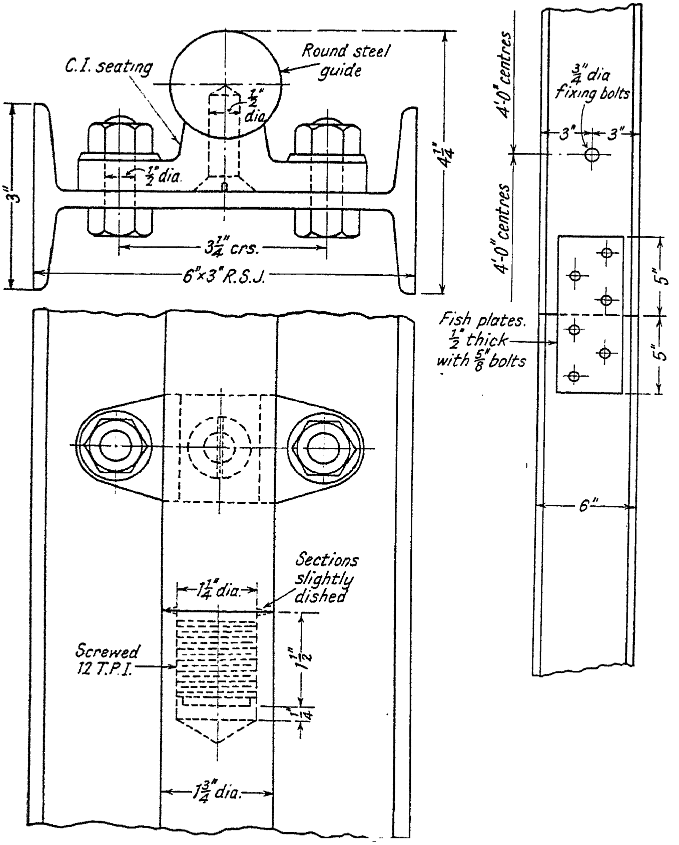


FIG. 100. METHODS OF FIXING AND JOINTING ROUND STEEL GUIDE AND BACKING

(*R. J. Shaw & Co.*)

therefore may be either a Lewis bolt or a through bolt fixed at the outer side by a steel plate.

A method of fixing round guides is shown in Fig. 99 in which the guide is secured at intervals of 4 ft. to cast-iron seatings, these being screwed to iron straps. The latter are fixed to the well by Lewis bolts or through bolts.

Fig. 100 shows a method of fixing round steel guides in which rolled steel backings are employed. These backings avoid the necessity of using large section guides in order to secure rigidity, and also enable the safety gear to operate on the backings, as shown in Fig. 101, instead of on the polished guides. The guide is fixed to cast-iron seatings by countersunk screws, these seatings in turn being bolted to the backings. The various lengths of guide are jointed by screwed socket joints, whilst the lengths of backings are jointed by steel fishplates. A spacing of about 4 ft. is adopted for the bolts which secure the backings to the well.

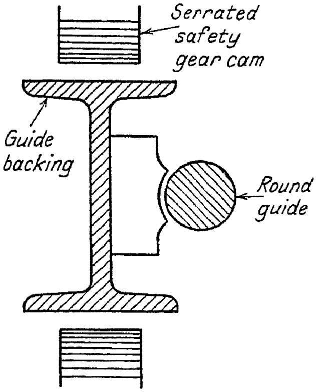


FIG. 101
OPERATION OF SAFETY GEAR ON GUIDE BACKING

Many different methods are employed for fixing tee-section guides, some of these being illustrated in Figs. 102 and 104. Fig. 102 shows the method of jointing tee-guides and of fixing the car guides to the well. The lengths of guide are jointed by machined spigot and socket joints along the web, and in some cases along the flange as well; the flanges being machined and jointed by a machined steel fishplate. The guide is fastened to steel plates at intervals of about 6 ft. by malleable iron clamps, a typical example of which is shown in Fig. 103. The back plates are secured to the well by through bolts or Lewis bolts, spacing pieces being interposed between the plates and the well. Alternatively, the back plates, either flat or angle iron, may be bolted to the steel well structure.

Fig. 104 shows methods of fixing car and counterweight guides when landing openings on opposite sides are required, and it becomes necessary to fix a car guide on the same wall

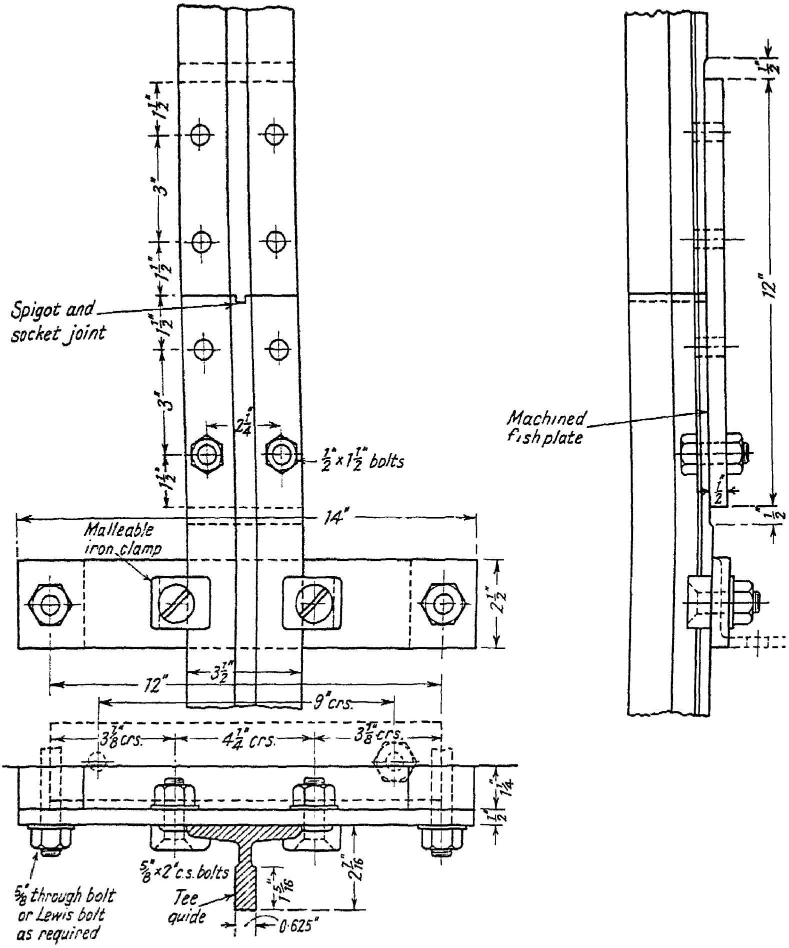


FIG. 102. ARRANGEMENT OF CAR GUIDE FIXED TO WALL OR STEEL STRUCTURE

Showing method of jointing

(*R. J. Shaw & Co.*)

as the counterweight guides. In (*a*) the counterweight guides are fixed to channel irons by the usual clamps, these channels being fixed to the well every 6 ft. Similar spacing is adopted for the car guide fixings, the guides being secured to iron straps which brace the two channel irons. In (*b*) a similar result is obtained by using iron straps instead of angles.

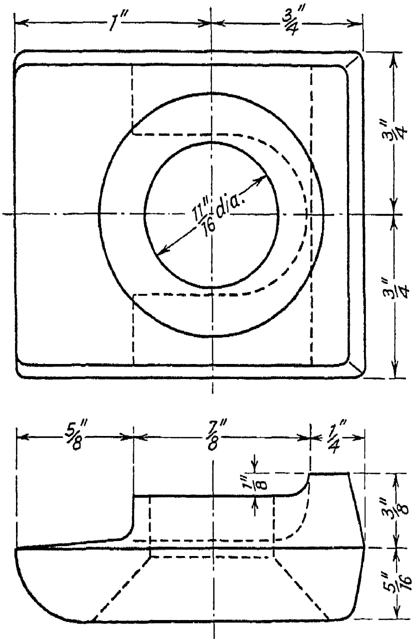
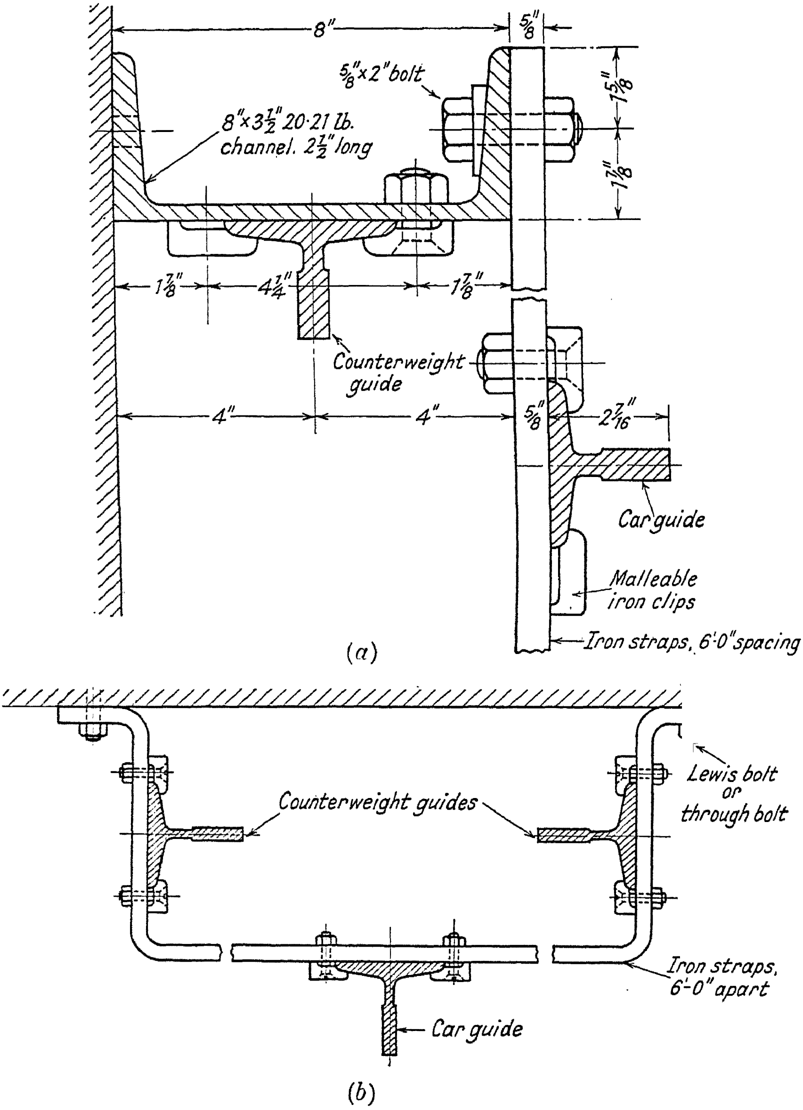


Fig. 103. Malleable Iron Guide Clamp for Tee Guides
(*R. J. Shaw & Co.*)

Other methods of fixing counterweight guides and counterweight guards are shown in Fig. 105. In (*a*) the guides are secured to the well by angle irons, and in (*b*) by short lengths of angle, either embedded in the well or bolted to the steel structure. A bracket for attaching the counterweight guard to the counterweight guides is shown at (*c*).



(a)

(b)

FIG. 104. METHODS OF FIXING CAR AND COUNTERWEIGHT GUIDES

(a) Car guide fixed to counterweight guide brackets
(b) Car guide fixed to counterweight guide straps

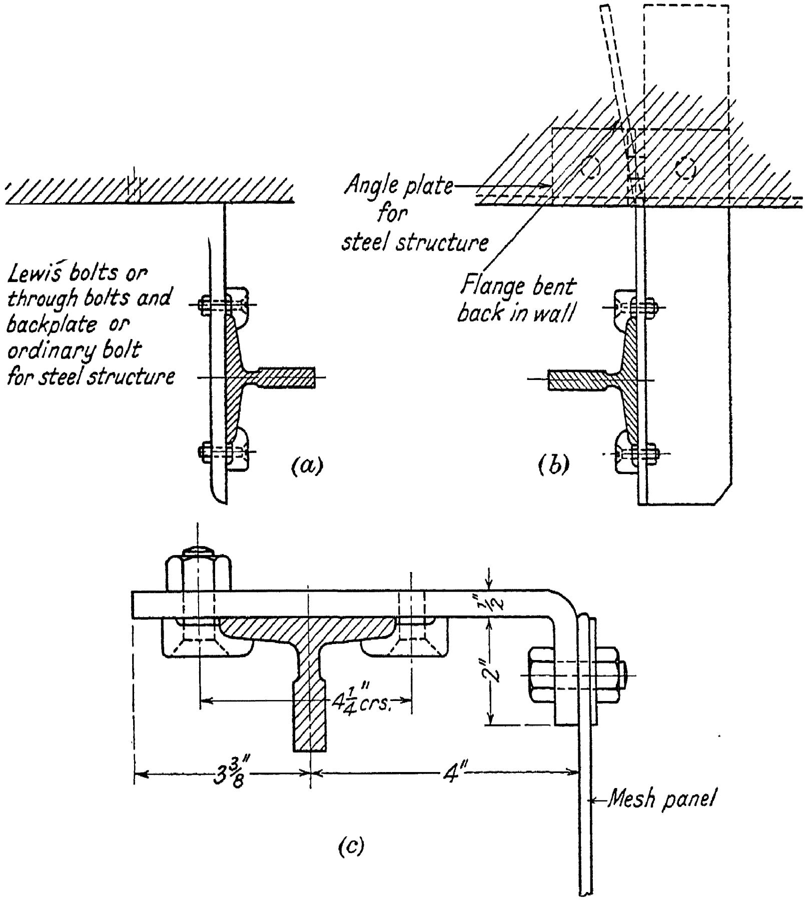


FIG. 105. COUNTERWEIGHT GUIDES AND GUARDS

(*a*) and (*b*) Other methods of fixing counterweight tee guides
(*c*) Bracket to fix wire mesh guards to counterweight guides

(*R. J. Shaw & Co.*)

CHAPTER X

GATES, DOORS, AND LOCKS

GATES AND DOORS

Gates. The most common form of protection for lift car and landing entrances is the collapsible iron gate of the overhung type. The gate is supported by ballbearing rollers running on an overhead track as shown in Fig. 106, the pickets being guided by a specially shaped bottom track. Lift cars are frequently equipped with close spaced gates such as the mid-bar and "Nu-bar" types in order to minimize the possibility of a passenger passing his foot between the pickets when the car is in motion. These close spaced gates are sometimes fitted to both car and landings. Mid-bar gates are either of the half or full types as depicted in Figs. 107 and 108. The "Nu-bar" gate gives the narrow safety spacing desired, without the use of mid-bars, the gate being constructed with a double channel vertical at the front and back, but the intermediate verticals are fitted alternately on either side of the lattice, giving half the spacing of verticals compared with the ordinary gate, while bunching into practically the same space. This arrangement means that every joint in the lattice has to be tightly riveted and the gate will therefore stand a great deal of abuse, whilst the repair of a damaged gate is a comparatively simple matter, when the gate is in position. A hollow tube gate construction is sometimes adopted, the tubes frequently being made of aluminium and arranged to run around the side of the car when opened, thus giving an opening equal to the full car width. These gates may be of the single side opening or double centre opening types as in Figs. 109 and 110 respectively.

Doors. On most modern high grade passenger lifts, doors of various types are superseding gates, particularly for landings, the main advantages of the former being, elimination of draughts emanating from the well, prevention of noise being transmitted to various floors via the well openings, and improved appearance. Some of the types of doors in use are detailed below.

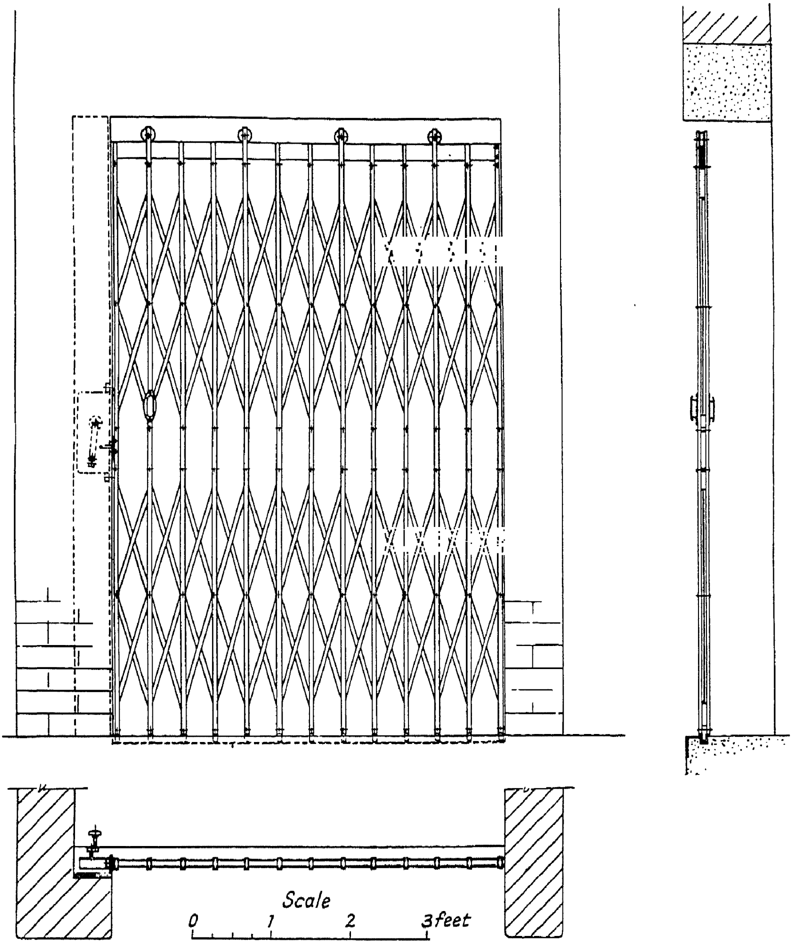


FIG. 106. COLLAPSIBLE GATE

(Wm. Wadsworth & Sons)

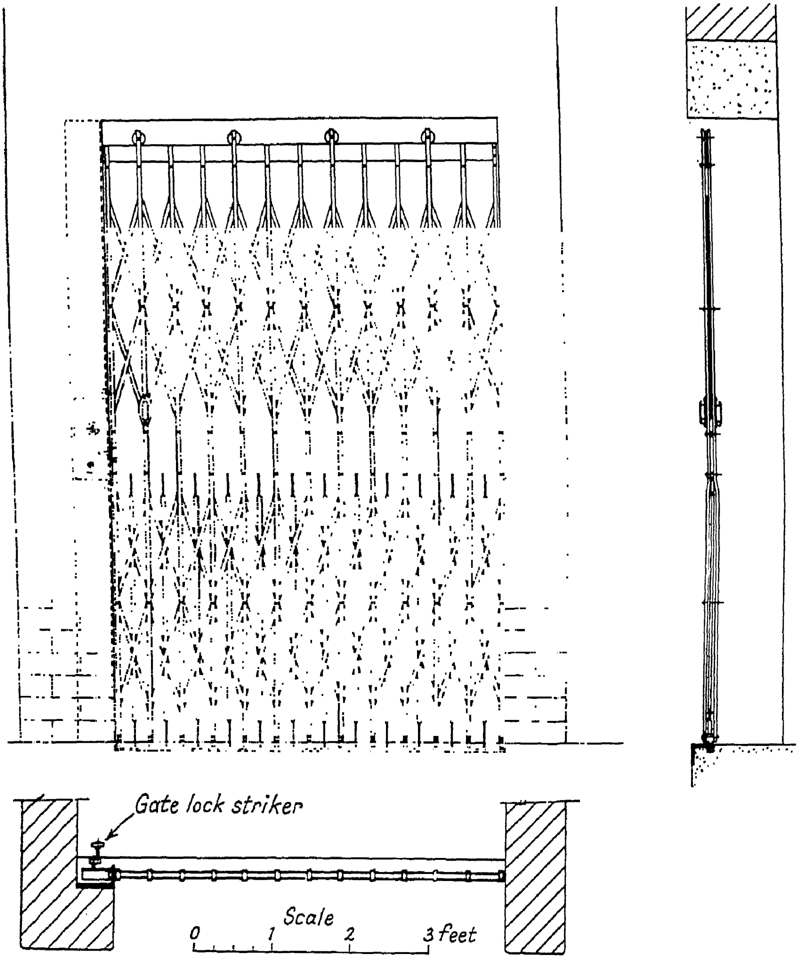


FIG. 107. COLLAPSIBLE GATE: HALF MID-BAR TYPE
(Wm. Wadsworth & Sons)

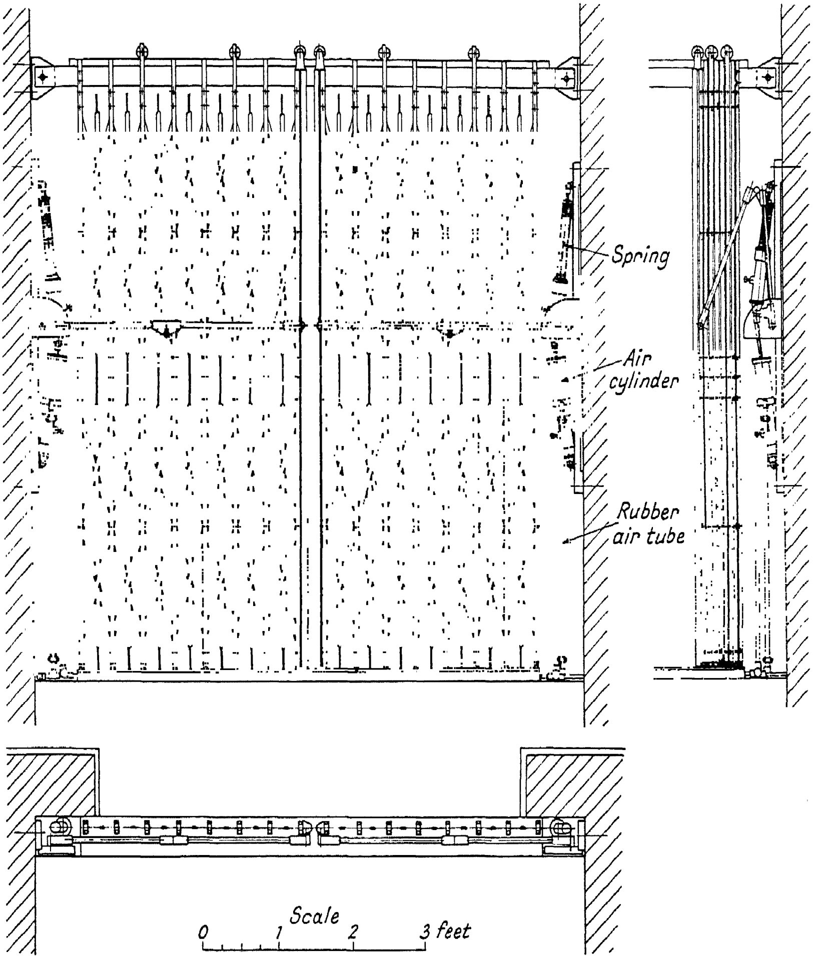


FIG. 108. COLLAPSIBLE GATE: MID-BAR TYPE
Automatic opening and closing: power driven
(*Wm. Wadsworth & Sons*)

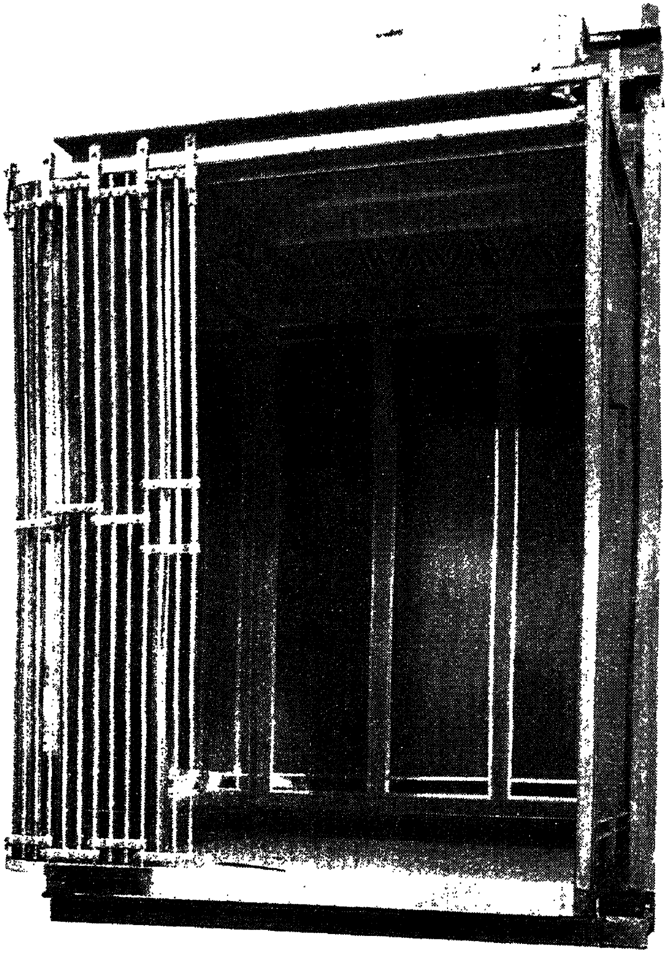


FIG. 109. SINGLE HOLLOW TUBE GATE FITTED TO PASSENGER CAR
(*Wm. Wadsworth & Sons*)

COLLAPSIBLE STEEL SHUTTER DOOR. This type is frequently fitted on the landings of goods lifts, and has the advantage of minimizing the fire risk. A door of this type is shown in Fig. 111.

BALANCED RISE-AND-FALL DOORS. These are sometimes known as the *Peelle* type doors. They are arranged in two halves, of which the top half rises and the bottom half falls when the doors are being opened, as in Fig. 112.

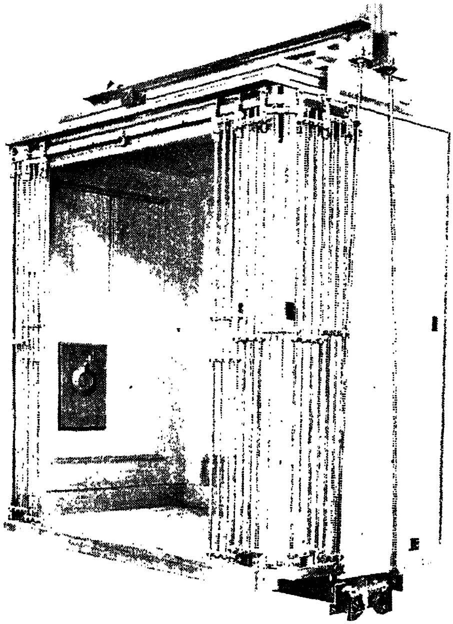


FIG. 110. DOUBLE HOLLOW TUBE GATE FITTED TO PASSENGER CAR
(Wm. Wadsworth & Sons)

SINGLE-HINGED DOOR. This opens outwards and is used on landings (Fig. 113).

DOUBLE-HINGED DOOR. In two parts, centre opening, and used on landings (see Fig. 90). The clear opening may be equal to the full car width.

SINGLE-LEAF SLIDE (Fig. 114). The clear opening is approximately half the width of the car.

Two-leaf, Two-speed Slide (Fig. 115). One leaf slides behind the other, the former at twice the speed of the latter, and both leaves therefore arrive at the fully opened position simultaneously. The clear opening is approximately two-thirds of the car width.

Two-leaf, Centre Opening Slide (Fig. 116). One leaf slides to the left and the other to the right. Rubber bumpers are fitted on the edges of each leaf to minimize the shock when opening and closing. The clear opening is about half the car width.

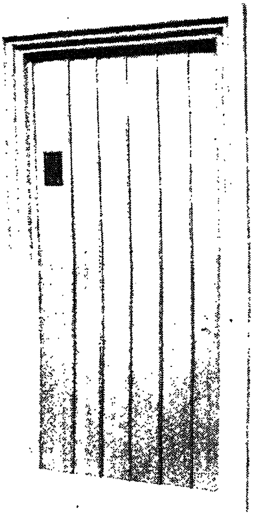


Fig. 111. Collapsible Shutter Door
(Marryat & Scott)

Two-leaf, Slide and Stationary (Fig. 117). The sliding leaf moves behind the stationary leaf and the opening is therefore only equal to the width of the sliding leaf, which is about half the width of the car.

Two-leaf, Slide and Swing. Shown in Fig. 118. Used on passenger lifts in which packing cases or trunks are occasionally carried. For normal passenger service the sliding door is used,

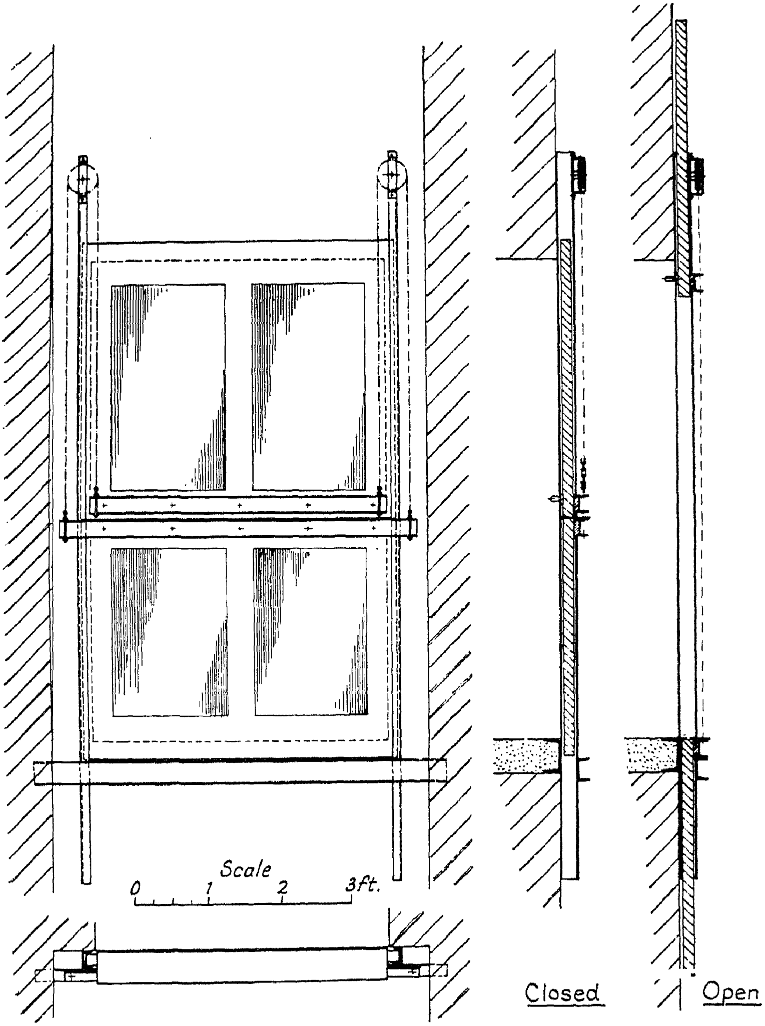


Fig. 112. Peelle Type Balanced Door
Fireproof doors with rubber end buffers
(*Wm. Wadsworth & Sons*)

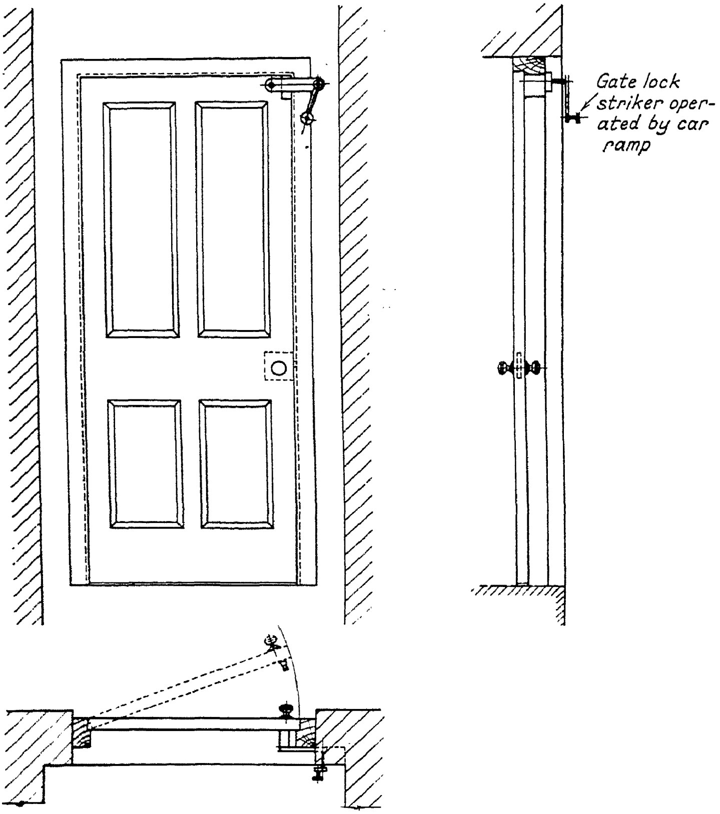


FIG. 113. SINGLE-HINGE LIFT DOOR
(*Wm. Wadsworth & Sons*)

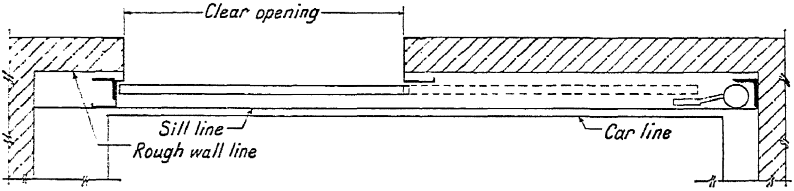


FIG. 114. SINGLE-SLIDE LIFT ENTRANCE
(*Waygood Otis, Ltd.*)

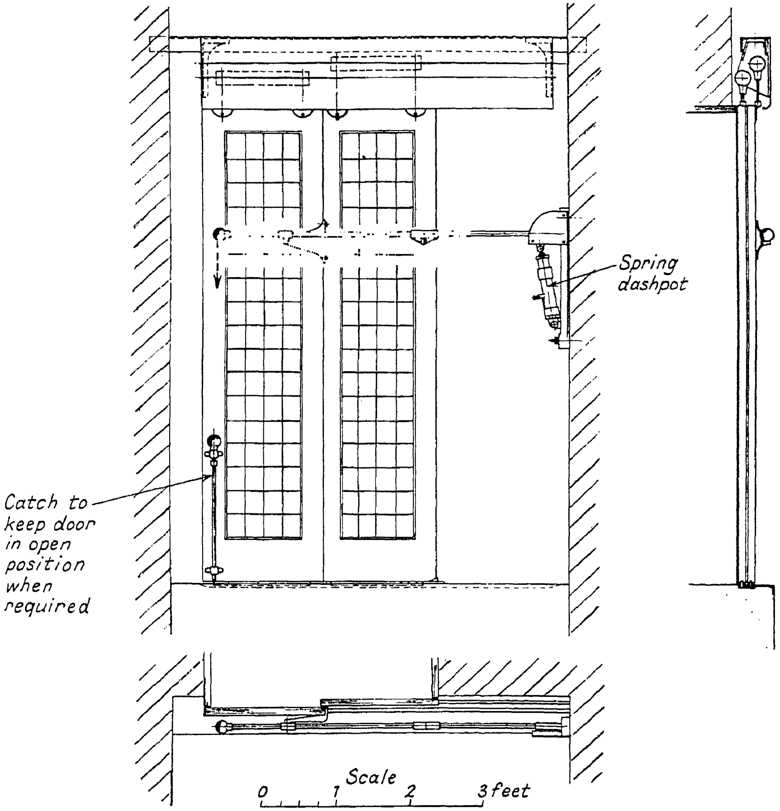


FIG. 115. TWO-SPEED SLIDING DOORS WITH AUTOMATIC CLOSER
(*Wm. Wadsworth & Sons*)

but when large cases have to be handled the swing door may be opened in addition to the sliding door. The sliding door top rail is fixed to the swing door and arrangements are made so that the sliding door can readily be disengaged from its bottom track.

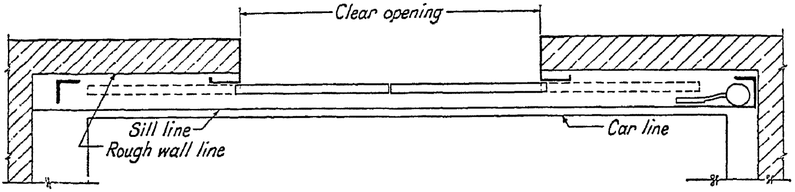


FIG. 116. TWO-LEAF, CENTRE OPENING, SLIDE LIFT ENTRANCE
(*Waygood Otis, Ltd.*)

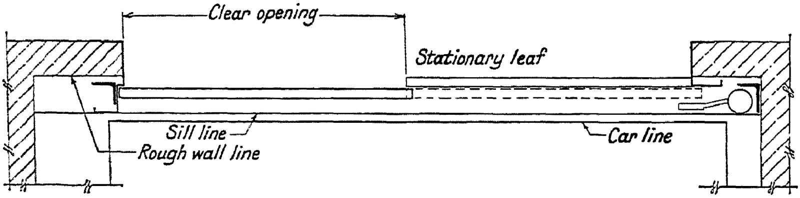


FIG. 117. TWO-LEAF, SLIDE AND STATIONARY, LIFT ENTRANCE
(*Waygood Otis, Ltd.*)

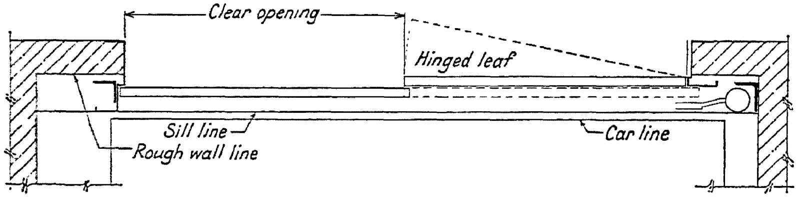


FIG. 118. TWO-LEAF, SLIDE AND SWING, LIFT ENTRANCE
(*Waygood, Otis Ltd.*)

THREE-LEAF, TWO-SPEED SLIDE AND STATIONARY. The two sliding leaves move behind the stationary leaf, one at twice the speed of the other, so that both leaves arrive at the fully opened position simultaneously. This type of opening is adopted where it is desirable to produce architectural symmetry in the corridor treatment for landing openings which would be off centre or improperly located with any other type of entrance. The opening is approximately two-thirds the car width. (See Fig. 119.)

THREE-LEAF, TWO-SPEED AND SWING. As in Fig. 120.

FOUR-LEAF SLIDE, TWO-SPEED CENTRE OPENING. Two leaves slide to the left, one at twice the speed of the other, the remaining two leaves similarly slide to the right as shown in Fig. 121.

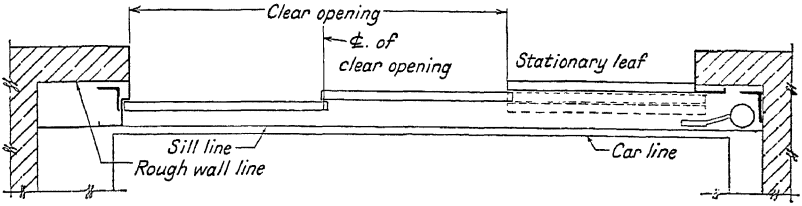


FIG. 119. THREE-LEAF, TWO-SPEED SLIDE AND STATIONARY, LIFT ENTRANCE
(*Waygood Otis, Ltd.*)

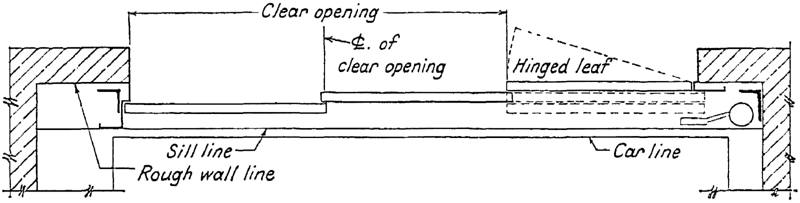


FIG. 120. THREE-LEAF, TWO-SPEED SLIDE AND SWING, LIFT ENTRANCE
(*Waygood Otis, Ltd.*)

Sliding doors are invariably overhung, the bottom edges being provided with rectangular guides that travel in the machined grooves of the sills. Rubber bumpers are fitted on the entrance framework to minimize shocks when opening and closing. Doors may be constructed of wood and finished to harmonize with the surrounding landing architecture. Probably the best practice, however, is to use sheet steel No. 14 or No. 16 gauge, suitably framed and filled and reinforced if necessary to receive the operating mechanism. The advantages of sheet steel doors are that there is no tendency to lose shape, as is the case with wooden doors, and the fire risk is lessened.

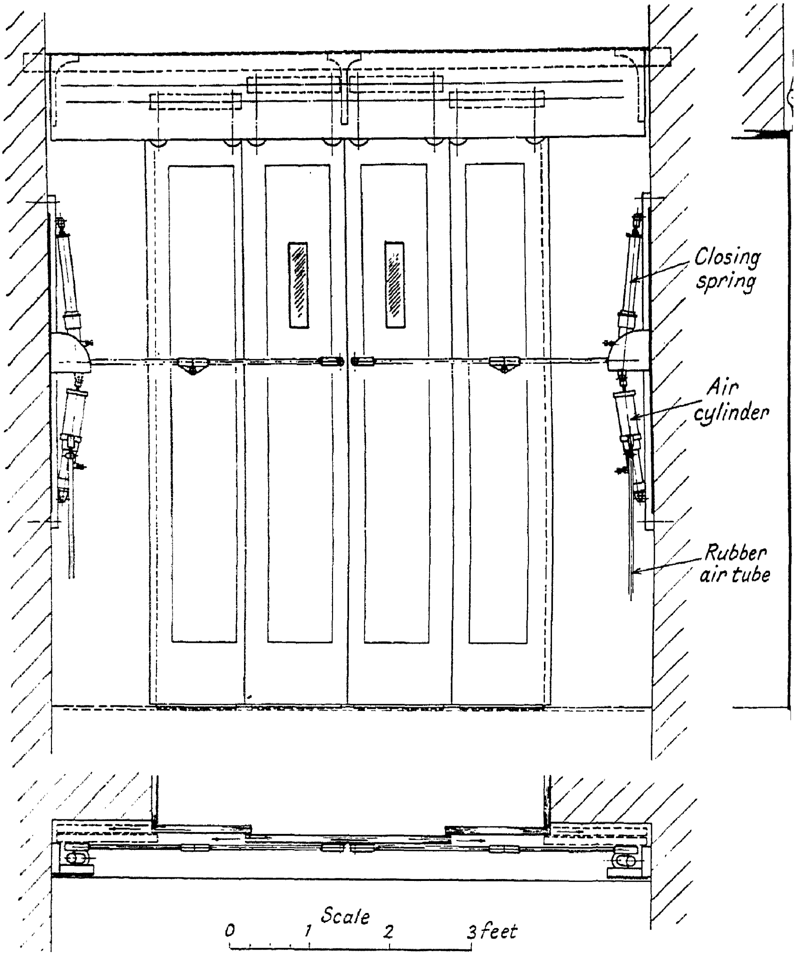


FIG. 121. FOUR-LEAF SLIDE, TWO-SPEED, CENTRE OPENING DOORS
With pneumatic opening gear
(*Wm. Wadsworth & Sons*)

A large number of door designs is available, some having solid panels, others glass vision panels, these being varied by adding or rearranging the panels. The decorative designs may be applied by stippling, stencilling, or a transfer process. Plain colours, grained, or bronze enamel finishes are very popular, whilst further decoration is sometimes obtained by means of strips of bronze, monel metal or non-oxide steel applied to the doors.

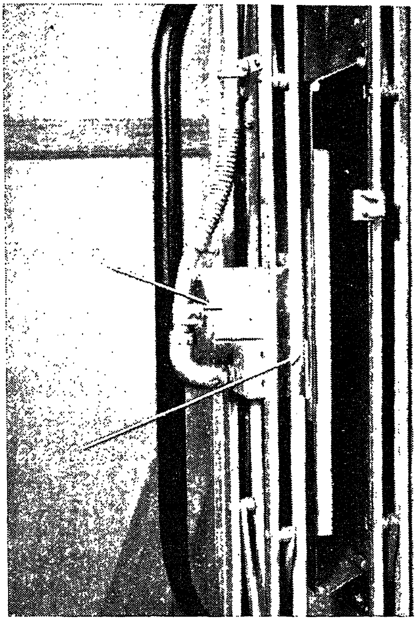


FIG. 122. ELECTROMAGNETICALLY COUPLED CAR AND LANDING GATES
(Both gates open)
(*Marryat & Scott*)

Methods of Operation. Collapsible gates or solid doors may be operated by one of the several methods detailed below.

MANUALLY OPERATED. The landing and car doors are opened and closed by hand after the car has arrived level with the landing and released the locks.

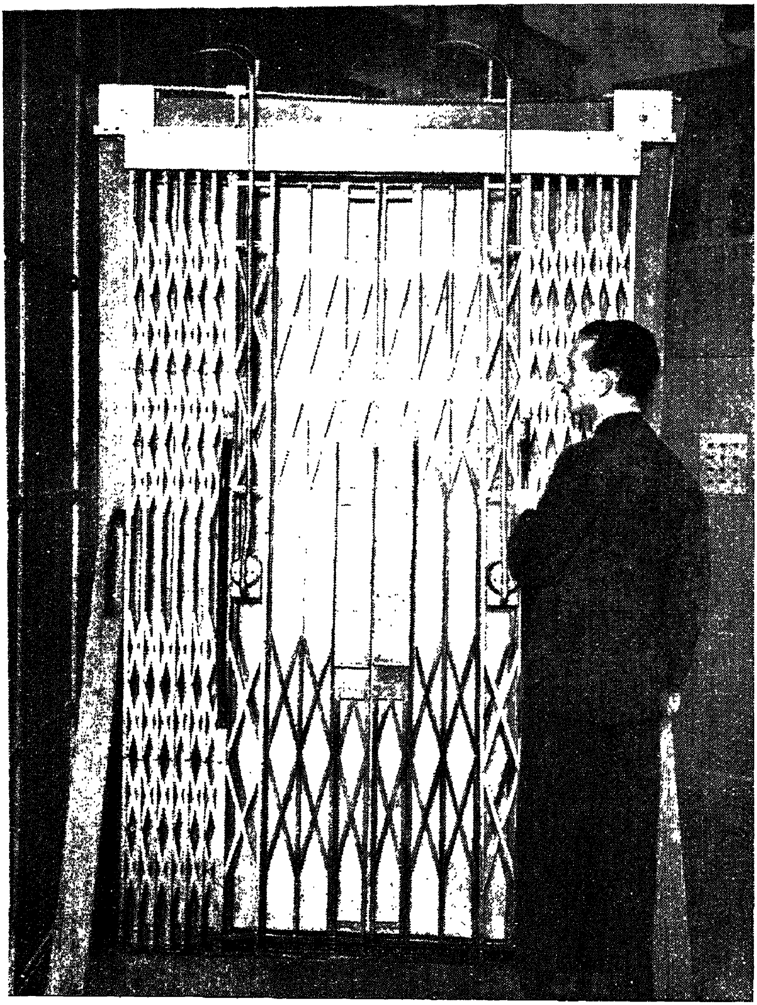


FIG. 123. ELECTROMAGNETICALLY COUPLED CAR AND LANDING GATES
(Electromagnet not operated)
(*Marryat & Scott*)

A patented method of reducing the labour involved in opening and closing the car and landing gates makes use of an electromagnet fitted to the car gate. This magnet, when energized, magnetically connects the landing and car gates together through the medium of a hinged iron plate fitted on the inside of the landing gate. Thus both gates are opened in one movement instead of two. The energized magnet with the connecting plate in position is shown in Fig. 122, whilst Fig. 123 shows the gear (not operated) fitted to centre opening gates.

SELF-CLOSING. In this form, the door or gate is opened manually but closes automatically when released. The closing is usually effected by means of springs, the action of which is cushioned by a dashpot (Fig. 124).

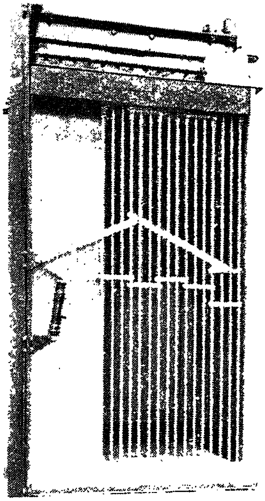


FIG. 124. SELF-CLOSING HOLLOW TUBE GATE
(Wm. Wadsworth & Sons)

AUTOMATIC OPERATION. The door is opened automatically by the action of the car approaching a landing, and closed automatically as the car leaves a landing.

Messrs. Waygood Otis' Type 20A door operator is an example of this type. When the car approaches a landing and the doors are to be opened, a cam on the side of the car is advanced by power and displaces a bell crank sill trip lever, thus raising the trip rod. This rod pivots the door swinging arm about its bearing, opening the doors. When the doors are to be closed the cam is permitted to withdraw by gravity, and a spring on the door arm closes the door.

SEMI-AUTOMATIC OPERATION. The door is opened manually and closes automatically as the car leaves the landing.

POWER OPERATION. In this form the door is both opened and closed by power, other than by hand, gravity, springs or the movement of the car. The power employed is either an electric motor or compressed air, the latter acting on a plunger in a cylinder, the plunger being connected to the door through a system of levers. If a failure of the electricity supply or air pressure occurs, the operating mechanism is so arranged that it may be readily disconnected and the doors operated by hand. High door operating speeds are only employed if means are adopted to prevent passengers being struck by doors. In one method of achieving this, photo-electric cells are used. The exciting lamp is fitted on one side of the entrance and illuminates a photo-electric cell fitted on the other side. When a person passes and interrupts the beam of light, the cell operates a control relay and prevents the closing of the door.

In one form of power operator, OPEN and CLOSE buttons are fitted in the car and at each landing. Momentary pressure of a button will cause the doors to open or close. In this case arrangements must be made to ensure that the landing buttons are only operative when the car is level with that particular landing.

In another type, the doors are opened and closed automatically by power as the car arrives at and leaves a landing respectively. The following is a brief description of Messrs. Waygood Otis' Type 30s door or gate operator, in which both opening and closing are performed automatically by an electric motor. The operator is designed principally for use with automatic and collective push button controlled lifts, and consists essentially of a small motor mounted above the gate track and operating the car gate by means of a swinging arm as shown in the sketch in Fig. 125. The apparatus includes the torque motor with a pinion driving a large gear segment which carries the swinging arm. A single-action dashpot retarder is connected to the swinging arm so as to cushion the movement of the gate or door in both directions. It is unnecessary to install a separate gate contact, as a switch for this purpose is incorporated as a part of the operator. The retiring lock release cam is also operated by the motor.

Instead of being both opened and closed by power, doors or gates are frequently opened by power and closed by springs, an example of which is Messrs. Waygood Otis' Type O operator shown in Fig. 126. This consists of a motor driving a crank disc through a reduction gear unit, the car door arm being operated from this disc by means of a chain. The apparatus is mounted on the top of the car and occupies a comparatively small amount of space. The harmonic motion transmitted to the doors by the crank disc gives the maximum door speed during mid travel, and hence a cushioning effect is obtained at both ends of the stroke. A dashpot retarder is also fitted, and this further cushions the movement of the door. The motion of the car door is transmitted to the landing doors by means of a cam secured to the former engaging a pair of rollers attached to the latter. These rollers are part of the landing door lock assembly which is so designed that when these doors are closed and locked, the rollers separate, providing running clearance for the cam. During the opening and closing operations the rollers are maintained close together, thereby connecting the

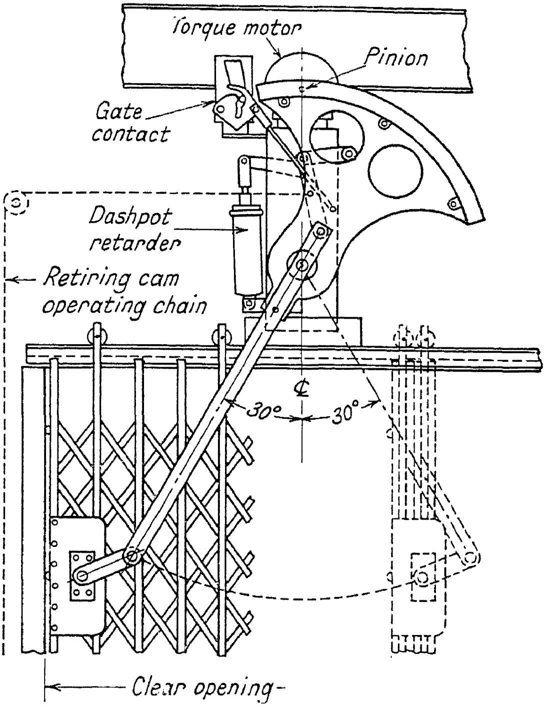


FIG. 125. GATE OR DOOR POWER OPERATOR
(*Waygood Otis, Ltd.*)

car and landing doors firmly to one another. The interlock switch is mounted on the header and suitable switches are provided to energize the door motor in both open and closed directions. This operator is for use on lifts with single-leaf slide car and landing doors, and where the latter are all of the same type and size.

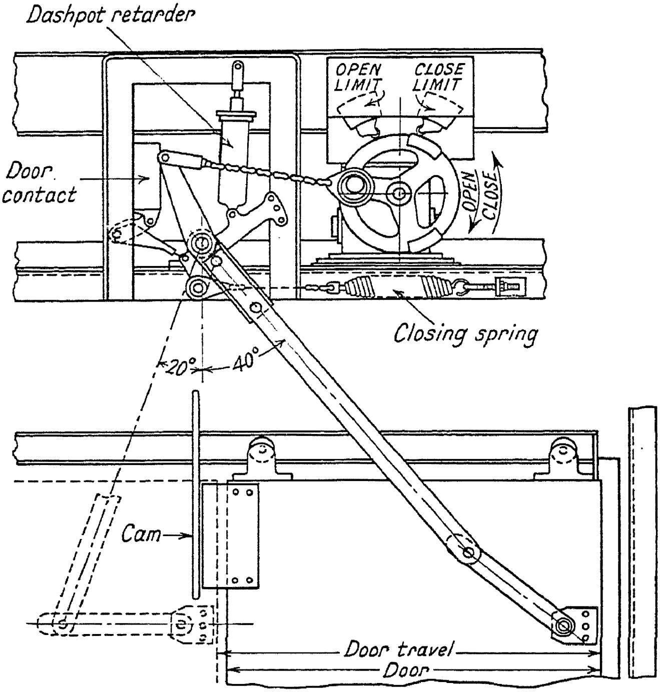


FIG. 126. LIFT DOOR OPERATOR
(*Waygood Otis, Ltd.*)

An operator in which the doors are opened by compressed air and closed by springs is shown in Fig. 87. A spring fitted in the air cylinder, behind the piston, cushions the movement of the doors during opening.

LOCKS

Car Gate or Door Locks. Every lift car gate or door is fitted with an electric interlock which prevents the movement of the car by cutting off the supply to the control circuit, unless the gate or door is properly closed. A car gate interlock of the gravity pattern is shown in Fig. 127. This lock is fitted to the top gate track in such a position that the leading picket raises the lock contact arm and short-circuits the two contacts when the gate is in the closed position. Immediately the gate commences to open, the arm drops due to the combined effects of gravity and a spring, and the control feed is cut off.

Cars having an entrance which opens into a space in any portion of the lift travel which is in excess of 5 in. should have the gate or door to that side of the car protected by a mechanical locking device with an electrical interlock.

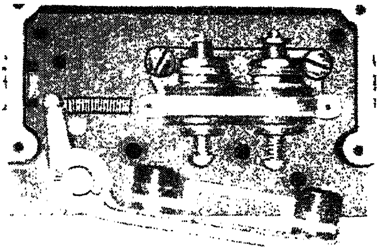


FIG. 127. CAR GATE INTERLOCK
(*Marryat & Scott*)

Car Gate Delayed Contact. It is frequently the practice, when a lift is worked on the automatic control system, to arrange that after a passenger has entered the car and closed both car and landing gates, a period of 5 to 10 sec. is allowed during which the landing buttons are cut out of circuit. During this period the car is under the sole control of the passenger in the car who is thus given time in which to select and operate the desired car button. If a car button is not pressed within the period allowed, the car may be called to any landing in response to pressure on a landing button. This facility is generally provided by incorporating an auxiliary delayed contact in the car gate lock box, this contact disconnecting the landing buttons from the control circuit for the desired period, immediately the gate is closed.

The principle of operation of this car gate delay switch is shown in Fig. 128. *A* and *B* are the two contacts of the car gate electric interlock whilst the contacts *C* and *D* are joined in the feed to the landing gate buttons. When the car gate is open, the weighted side of the lever *EF* is held away from the contacts *A* and *B* by gravity. The right side *E* is raised and holds the dashpot at such a height that it is clear of the contacts *C* and *D*. When the gate reaches its closed position the lever *EF* is pivoted about its fulcrum, the weighted side being raised by the roller coming in contact with the gate and the right side being lowered. This immediately causes the contacts *A* and *B* to be short-circuited, thus preparing the control circuit for the pressure of the car button, and at the same time the support *E* for the dashpot is removed. The dashpot cylinder now commences to fall, and in 5–10 sec. (this period is capable of adjustment) will reach the position when its roller will close contacts *C* and *D* and re-insert the landing buttons in the control circuit.

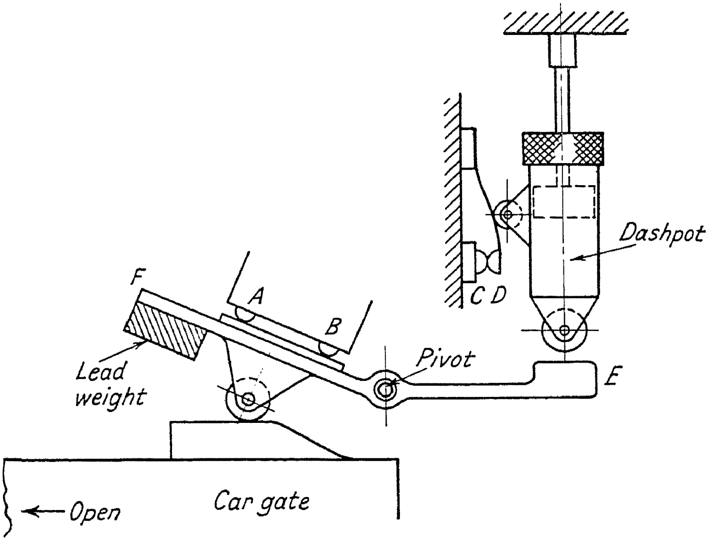


FIG. 128. CAR GATE DELAY SWITCH

Landing Gate or Door Locks. Several different types of locks are employed for landing gates or doors, the particular lock used depending upon the method of operation of the gate or door. The main object of all types, however, is to ensure that the gate or door cannot be opened until the car is either level with the landing or within that particular landing zone.

Arrangements are sometimes made for the opening of the gate or door, in case of emergency, by means of a special key.

The most common form of locking system for landing gates and doors comprises a lock box which is fitted to the gate or door framing. The lock consists of a mechanical lock combined with an electric interlock, the control circuit being completed (except for pressure on a car or landing button or the operation of the car switch) when the electrical interlock is operated. The door is mechanically locked before the interlock makes contact. Hence, before the mechanical lock can be released to open the door, the electrical interlock must be broken, thus disconnecting the control circuit. A lock of this type is illustrated in Fig. 129. The electrical interlock is housed in the top portion of the box and the mechanical lock in the bottom. When locked, the gate can only be opened by releasing the operating lever, and as this lever can be placed inside the well in almost any position, by using an extended operating rod, the possibility of interference from the landing is eliminated. The operating lever is released by a cam on the car coming in contact with the lever roller when the car is within that particular landing zone. The locking bolt is then released and the interlock contacts opened, thus permitting the opening of the gates. When the latch tongue is drawn free of the rotating cam and the gate commences to open, the tongue is arranged to fold back flush with the front picket of the gate, thus leaving no projection likely to damage clothing of passengers when entering or leaving the car. During the closing of the gate the electrical interlock is not made until the locking movement is complete.

Another locking system employed is that in which the lift is operated only from the car, and is provided with solid sliding landing doors which are equipped with a door closer and are locked with a mechanical contrivance actuated by means of levers operated from the car side only. An example of this is incorporated in Messrs. Waygood Otis' Type O operator. The door is considered closed and the car may be moved away from the landings when the door is within 4 in. of the jamb, or in the case of centre opening doors, when these are within 4 in. of each other, provided an approved attachment is fitted which will effectively prevent the doors from being re-opened after they have reached a limit of 4 in. and provided also that

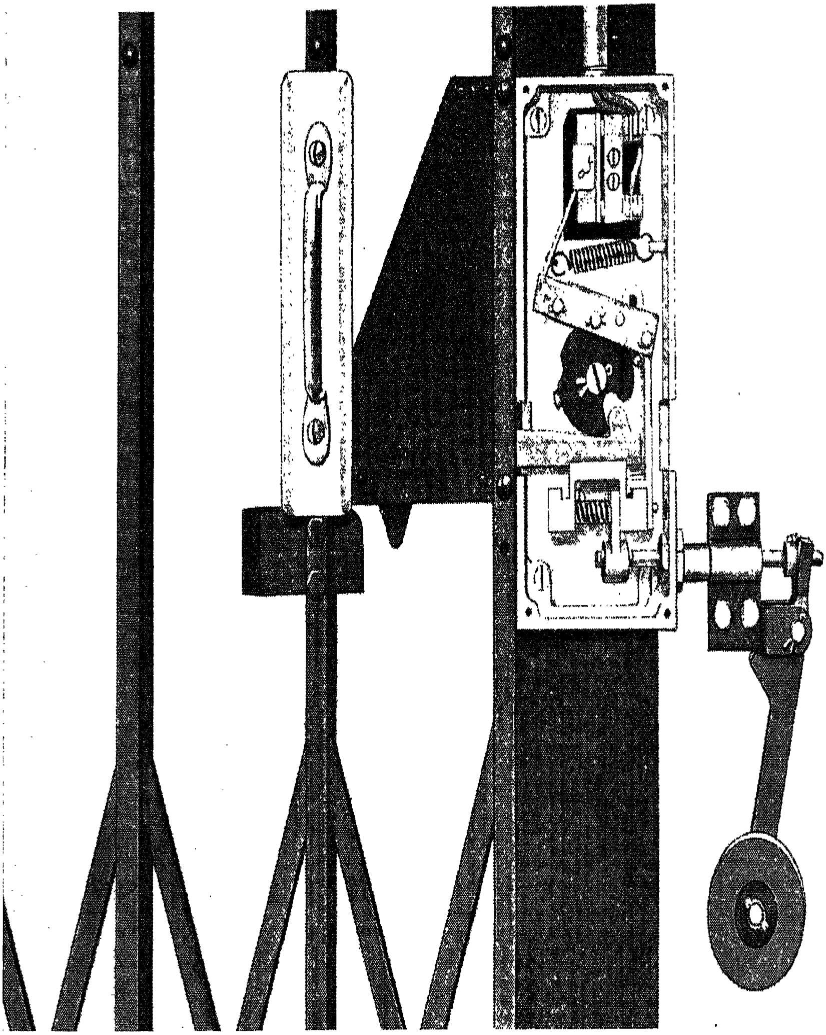


FIG. 129A. LANDING GATE LOCK

(Closed position)

(*Etchells, Congdon & Muir*)

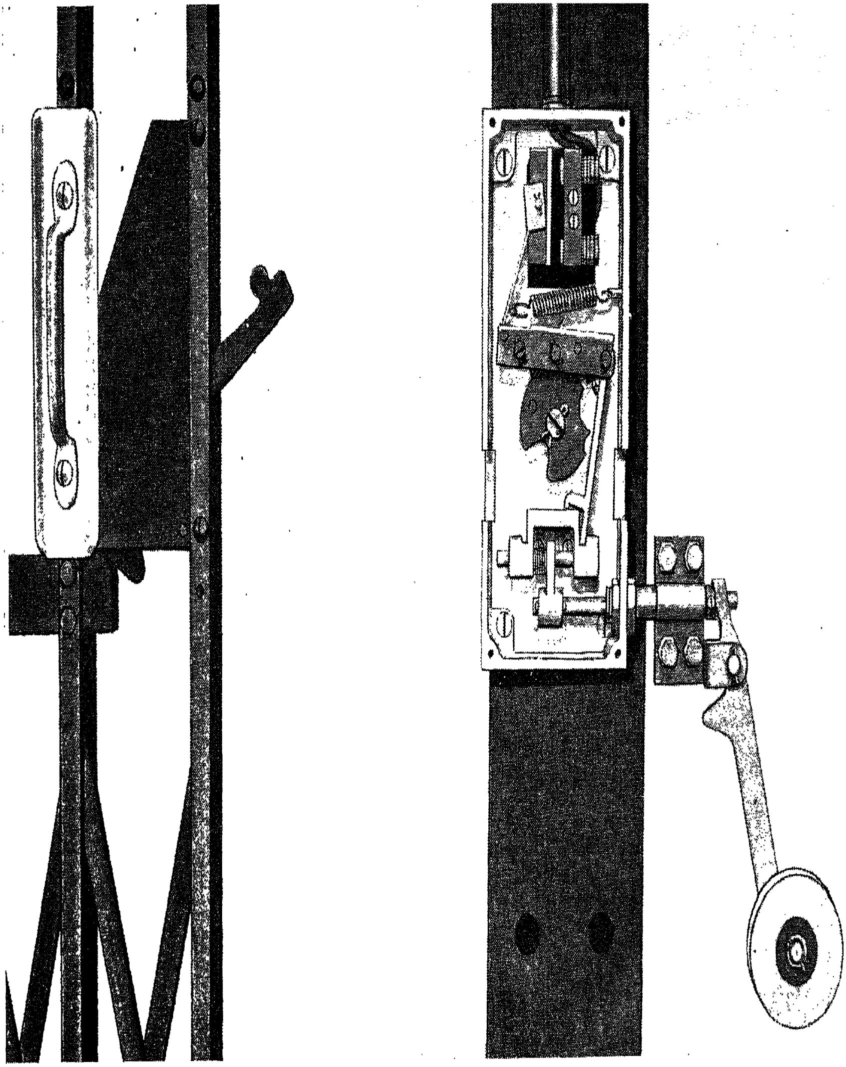


FIG. 129B. LANDING GATE LOCK

(Open position)

(Etchel's, Congdon & Muir)

the door closer is of such a type as will eventually carry the door to, and lock it in the closed position.

When an automatic type of control is employed and the landing doors are of the solid sliding type, equipped with a door closer, the doors may be locked mechanically by means of levers.

For service lifts, the mechanical locking unit may be separate from the electrical interlock.

Lock Requirements. All parts of the lock should be of substantial design and construction, and the locks must be so arranged that the electrical interlock is not made until the gate or door is closed. The contacts of the interlock should be of the solid type, and the insulation should be capable of withstanding for 1 min. a pressure of 2 000 volts a.c. The levers operating the mechanical part of the lock should be protected from interference from the landing side of the enclosure. Any spring used in the lock construction should preferably be in compression. When the emergency release push is in temporary use, or when the car is being moved under the control of the levelling gear, the lock should not prevent the operation of the lift.

In addition to the above, provision should be made on lifts operated from the car and landings to prevent the opening of any landing gate or door when the car is passing that zone in response to a call from another landing. The gate lock is operated by a cam fixed to the car, the cam hitting the gate lock arm when the car reaches a landing. On a large number of lifts the cam strikes the gate lock arm as each landing is reached, irrespective of whether a stop is required. With a lock of this type, it will be appreciated that it is possible for a person at a landing to snatch open the door or gate as the car passes. This bad practice, apart from the possibility of temporarily putting the lift out of service, is liable to cause damage, since the gate contacts are not designed to break current. The above requirement is therefore highly desirable and on most modern lifts having a travel of more than two floors a device known as a *retiring lock release cam* (Fig. 130) is fitted, thus making it impossible for the cam to operate the gate lock, except at the landing where a stop is to be made. The cam is withdrawn beyond reach of the gate lock arm by means of an electromagnet which is energized at all times when

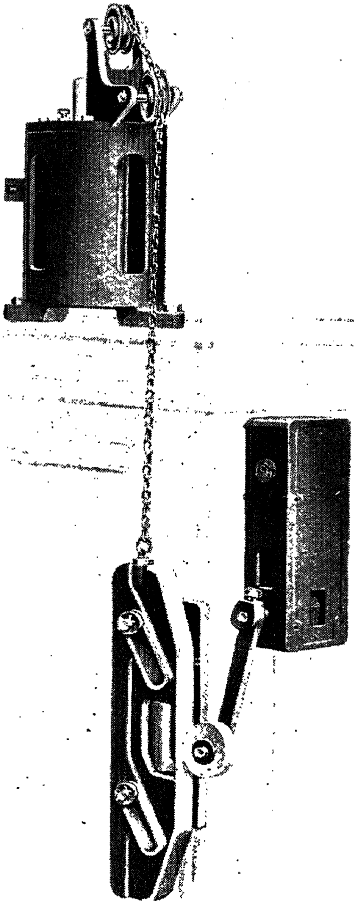


FIG. 130. RETIRING LOCK RELEASE CAM
(Etchells, Congdon & Muir)

the car is outside the particular landing zone where a stop is required. When stopping, the electromagnet is de-energized and this releases the cam and enables it to operate the gate lock. When power operated gates are employed, the retiring cam is frequently operated by the gate motor and a separate electromagnet is therefore unnecessary.

Wiring of Locks. The electric cables to the lock contacts should be run in conduit, which should be securely fixed to the lock box and be in electrical and mechanical continuity. The contacts must be wired in the control circuit in such a manner that the car cannot be started or kept in motion between landing zones, unless all landing and car gates are closed and their interlocks consequently made. The landing zone is the space between positions not more than 15 in. above and below the landing level.

The usual method of wiring the lock contacts is to arrange for the supply to the control circuit to pass through the contacts, and this is satisfactory under normal conditions, With three-wire systems of supply, however, it is possible, if an earth fault develops, for the lift to be operated with the gates open, which is a highly dangerous condition.* Assume that the locks are joined in the positive or line feed to the control circuit which is fed from the outers of a three-wire d.c. or a.c. supply, the centre or neutral wire being earthed. An earth fault occurring between the locks and the controller contactors will blow the +ve or line fuse but will leave half the control voltage fed to the coils, and this feed will not be controlled by the gate locks. This voltage may be sufficient to operate the contactors, but will certainly maintain them if the lift is in operation when the fault occurs. A solution to this difficulty, and one which renders an earth fault harmless, consists in operating the control circuits from the low voltage side of the supply, i.e. between +ve or –ve, and earth or line and neutral. If the low voltage main is not available, fuses of a special type may be used in the control circuit, these fuses being constructed so that the fuse wire is connected in one side of the supply and supports a contact connected in the other side. If one fuse is in each main, the blowing of either fuse will cause the opposite side to be disconnected.

---

* "Lift Control Gear," by A. Read, *Electrical Review*, 5th April, 1935.

The general practice now is to use a d.c. controller, the supply for which is obtained from rectifiers when the mains are a.c. The gate locks are usually connected in one of the rectifier d.c. feeds to the control circuit. The rectifier may consist of a three-phase network, a single-phase double-wave network from outer to outer, or a single-phase double-wave network from outer to neutral, but in each of these cases an earth fault may cause the contactors to be fed by half-wave impulses not controlled by the locks. Complete safety may be obtained by joining the locks in the a.c. live main before it reaches the rectifier. When the rectifier is fed from the outers of the a.c. supply, the locks may be joined in, say, the +ve d.c. main from the rectifier and the –ve rectifier main earthed.

CHAPTER XI

INDICATORS

Car Indicators. Some form of indicator in the car is necessary with car switch controlled lifts so that the attendant shall be made aware of the floors at which persons are waiting. It is also necessary, with some forms of control, that indications be given of the directions in which the persons wish to travel. Several different forms of car indicators are available, some employing electromagnetically operated targets, and others electric lamps.

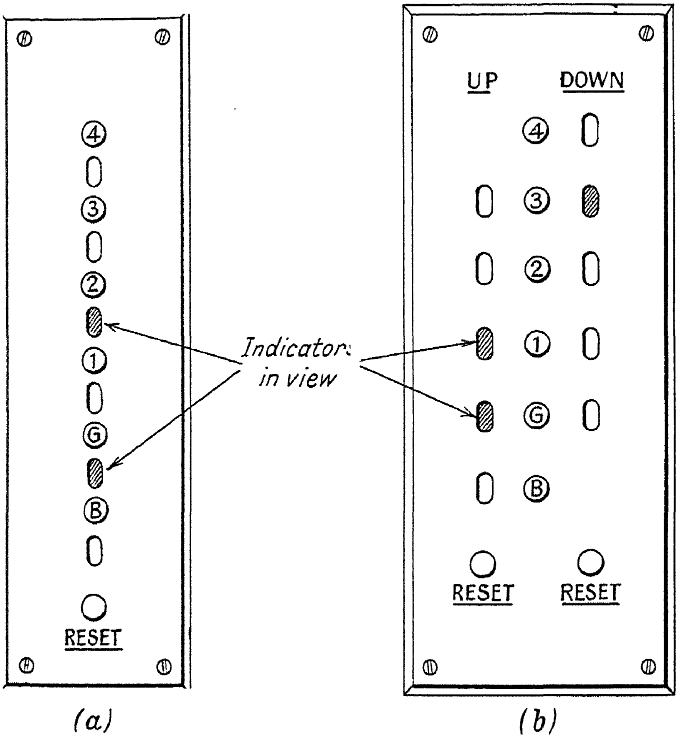


FIG. 131. TARGET INDICATOR
(a) Single indications (b) Up and down indications

In the target indicator, the magnet targets are operated and made visible when the landing call pushes are pressed. The unit comprises one magnet-operated target for each floor served, a controlling relay, and a buzzer. On the operation of a landing call button, a magnet moves the corresponding target into view, thereby registering the signal in the car. After the call has been answered, pressure of the reset button (fitted on the car indicator unit) energizes another magnet and moves the target out of sight. Alternatively, the resetting magnet can be energized by the arrival of the car at the desired floor, in which case the target remains set until the call has definitely been answered. The buzzer gives an audible signal when the call is made and registered. Fig. 131 (*a*) shows a single indicator of this type, and Fig. 131 (*b*) a double indicator. The former indicates only the floor at which service is required, whilst the latter indicates, in addition, the direction in which the caller wishes to travel.

Another form of car indicator for use in attendant operated lifts is shown in Fig. 132, and comprises a luminous bull's eye and a cancelling button for each floor. Each bull's eye glows when operated by the corresponding landing button, and the calls may be cancelled singly by the attendant as and when answered. A buzzer is provided to draw attention to the fact that calls are being made.

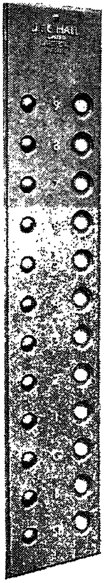


FIG. 132. CAR INDICATOR
(*J. & E. Hall, Ltd.*)

A typical wiring diagram for an indicator similar to that in Fig. 132 is shown in Fig. 133, the operation of the circuit being as follows. Pressure on, say, the ground floor landing push completes the circuit from +ve line through the ground floor relay, ground floor push, ground floor reset button to –ve line. The operation of the ground floor relay closes its contact and thus provides a holding circuit for the relay via its contact, bottom contact of ground floor push and ground floor reset push, this circuit being independent of the operation of the landing push. A parallel circuit via the relay contact illuminates the ground floor indicator lamp. During the operation of the landing push, a circuit is provided for the buzzer via the ground push and reset button, this circuit being broken when the push is released. After the call has been answered, the reset button is operated and this disconnects the relay circuit, opens its contact and extinguishes the lamp.

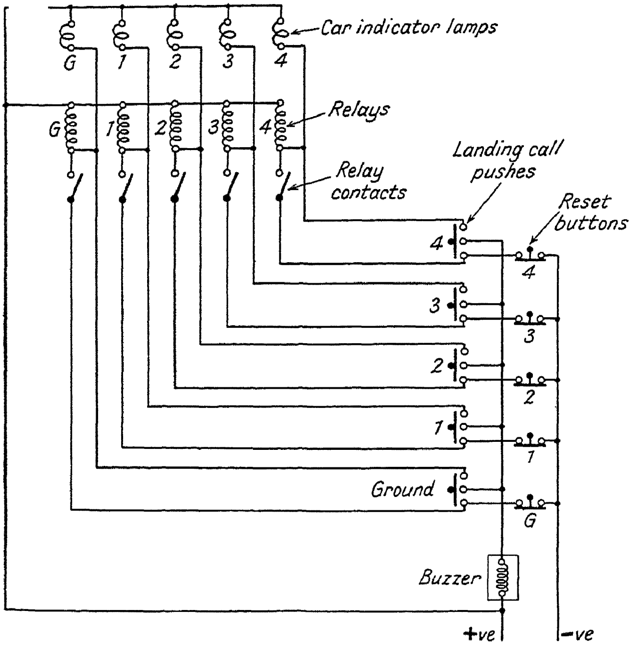


FIG. 133. CAR INDICATOR WIRING DIAGRAM

Another type of indicator somewhat similar to that above dispenses with reset buttons, the extinguishing of the lamps being performed automatically as the calls are answered. The relay and lamp circuits are disconnected by the opening of contacts on the landing gates, and the calls therefore remain registered until the corresponding landing gates are opened. The circuit is the same as that shown in Fig. 133, except that the reset buttons are replaced by the landing gate contacts. As in the case of the target indicator, a double row of lamps may be installed in the car when it is desired that the attendant shall know the direction in which a person wishes to travel.

An intercommunication system between each car and the landings has been developed for use when a bank of cars is operating in a building, and this ensures that only the nearest car travelling in the desired direction will answer a landing call. With this system, pressure on any up or down landing button illuminates the corresponding white up or down lamps in all cars. The attendant of the nearest car, which has sufficient room and is travelling in the desired direction, then presses a button corresponding to the floor. The operation of this button cancels the calls in all other cars and, in addition, signals to the landing which car will answer the call and illuminates a red lamp in the car, thus telling the operator where to stop. The car and landing signal lamps are automatically extinguished when the landing door is opened. For a signalling system of this type each intermediate landing requires an up and down call button, whilst the top and bottom terminal landings require only a down and up button respectively. Each car requires an up and a down signal lamp at every intermediate landing with single lamps at the terminal landings. On each car indicator, every intermediate floor position is equipped with a red and a white light for each direction of travel, i.e. a total of four lights, whilst the terminal landing positions on the car indicator have a red and a white light for only one direction of travel.

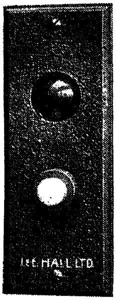


FIG. 134. "LIFT MOVING" INDICATOR
(*J. & E. Hall, Ltd.*)

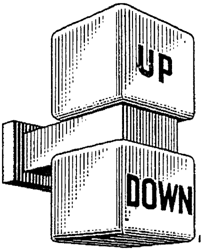


FIG. 135. DIRECTION INDICATOR
(*J. & E. Hall, Ltd.*)

Landing Indicators. To avoid impatience on the part of waiting passengers it is desirable to give some indication of the car's motion at the various landings. Indicators are available which show when the car is in motion, the direction of travel, and even the actual position of the car in the well.

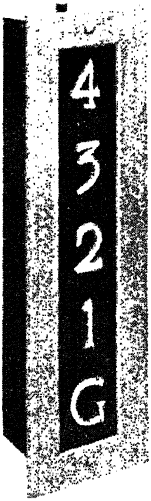


Fig. 136. Position Indicator
(*J. & E. Hall, Ltd.*)

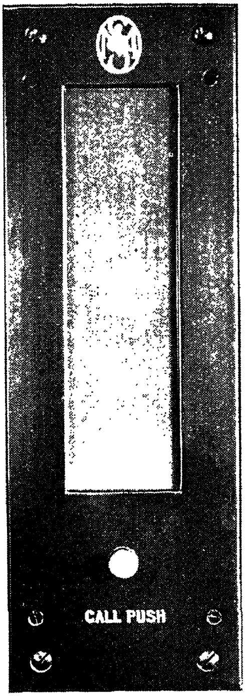


Fig. 137. Call Push and Car Position Indicator
(*Marryat & Scott*)

An illuminated bull's eye installed either adjacent to the call button as in Fig. 134, or above the landing entrance, is frequently fitted to indicate when the car is in motion and is useful, particularly when solid type landing doors are installed, and the well is, therefore, not visible to waiting passengers.

DIRECTIONAL INDICATORS. An additional feature, in which the light is arranged to glow either red or white, indicates when the car is travelling in the down or up directions respectively. Alternatively, the direction of travel may be shown by illuminated arrows or by illuminated signs, an example of the latter type being shown in Fig. 135. After the lift has passed each floor, the corresponding lamp is extinguished until the lift is again approaching.

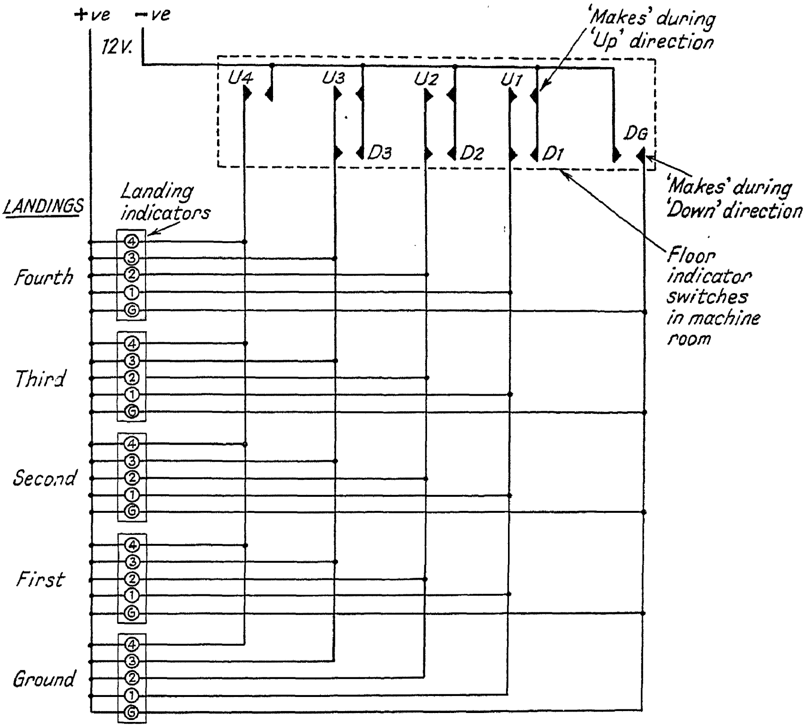

+ve
−ve
12V.
'Makes' during 'Up' direction
U4
U3
U2
U1
D3
D2
D1
DG
'Makes' during 'Down' direction
Floor indicator switches in machine room
LANDINGS
Landing indicators
Fourth
Third
Second
First
Ground
4
3
2
1
G

FIG. 138. LANDING INDICATOR WIRING DIAGRAM

POSITION INDICATORS. The tendency on most modern installations is to indicate the position of the car in the well, either with, or without, a separate direction indicator. A landing position indicator is shown in Fig. 136, the indicator being marked with embossed transparent glass letters, each illuminated singly as the car passes or stops at the various floors. A position indicator similar to that shown, but mounted horizontally and incorporating, in addition, illuminated direction arrows, is sometimes mounted above the landing entrances. Another form of combined call push and illuminated position indicator is shown in Fig. 137.

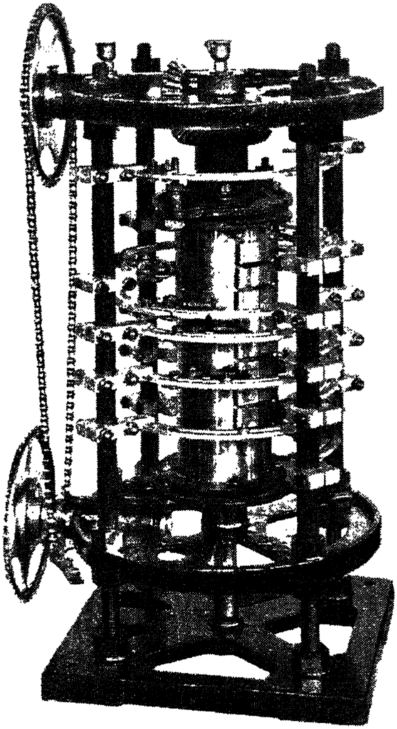


FIG. 139. ROTARY FLOOR INDICATOR SWITCH
(*Etchells, Congdon & Muir*)

The wiring diagram for a landing indicator system is shown in Fig. 138. Switches *U*1–4, *DG* and *D*1–3 are switches of a floor selector machine installed in the main machine room.

The selector machine is similar in construction and operation to the floor selector described in Chapter XIII or may be of the rotary drum pattern shown in Fig. 139. The selector shaft together with its operating arms is fixed to a pulley which is driven from the car by a steel flyrope, and each switch is arranged to close and open when the car approaches and recedes respectively from the corresponding landing. Switches U1–4 close during the upward motion of the car, whilst DG and D1–3 close during the downward journey, the switches opening and closing when the car is at half the distance between floors from the respective floors. As the car approaches the first floor in the downward direction, switch D1 closes and the circuits for the first floor lamps on each landing are completed via D1, this switch opening after the car has left the landing. Similarly, when the car is approaching any landing, the corresponding landing lamps are illuminated, the circuits having been completed through the U or D floor switches. If additional lamps showing the direction of travel are required on the indicators, then it is necessary to fit direction switches which may be operated by the main reversing contactors, one or other of these switches closing as the lift changes its direction of travel. The Up lamps are connected to one switch and the Down lamps to the other.

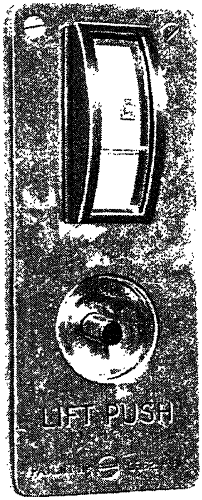


Fig. 140. Call Push and Car Position Indicator
(Marryat & Scott)

Another form of indicator consists of an illuminated miniature car and well fitted at each landing, the movements of the miniature car corresponding with that of the lift car. An indicator of this type, incorporating a call push, is shown in Fig. 140, in which a small car travels up and down in an illuminated window, in synchronization with the actual lift. The horizontal line on the window shows the position of the waiting passenger's floor in relation to the total car travel. The indicator illustrated is, in effect, a voltmeter which measures the potential difference between the end of a vertical current carrying wire in the well and that point on the wire which is in contact with the moving car.

CHAPTER XII

SAFETY FEATURES

CAR AND COUNTERWEIGHT SAFETY GEAR

SAFETY gear is invariably fitted to lift cars, with the object of preventing any uncontrolled movement of the car in a downward direction, by clamping the car to its guides should the lifting ropes break or the speed of the car, in descent, exceed a certain predetermined value. The gear is sometimes arranged to operate and clamp the car to its guides if the lifting ropes stretch unequally, as an additional safety to those mentioned above. Car safety gear is always fitted under the car framing, as cases have been recorded where the car has broken away from the safety gear when the latter has been fitted to the top of the car. Counterweights are sometimes provided with safety equipment in addition to that installed under the car, and this is invariably the practice when the lift does not extend to the basement, and occupied spaces are under the well. Three main types of safety gear for car and counterweights are in use, and the type adopted for any particular installation depends chiefly upon the maximum car speed employed.

Instantaneous Eccentric Cam Type. This gear, which is almost instantaneous in operation, is limited to speeds not exceeding 200 ft. per min. as, on account of the small stopping distance, the car and guides are subjected to heavy strains, whilst at speeds much in excess of 200 ft. per min. passengers would experience severe shock if the gear came into operation.

For light duty, the gear sometimes consists of two serrated steel cams fitted one on each side of the car and keyed to a connecting camshaft. The cams are eccentric in shape and normally travel just clear of the guides, being held away from them by a light return spring. When the connecting shaft is slightly rotated, the leading edges of the cams are brought into contact with the guides, the remaining motion of the cams necessary to clamp the car to the guides being automatically provided by the falling car. Either the camshaft, or one of the cams, is connected to the counterweight, or to the counterweight safety gear, if fitted, by means of a flexible steel flyrope which passes over an idle pulley at the top of the well. The safety flyrope is normally slack, but if the lifting ropes break or stretch unduly, the resultant tension placed upon the safety rope causes the cams to be drawn into contact with the guides and thus clamp the car. A diagram showing an arrangement of two single cams is given in Fig. 141 (*a*), in which the two cams are joined by a connecting link, this gear being suitable for a slow-speed counterweight, travelling in H-section guides. The safety rope passes from the car safety gear over a top idler, and is then secured to one of the counterweight cams. A direct pull on the safety rope, such as would be caused by a breakage or slackening of the lifting ropes, would cause both cams to operate. Another single cam type gear fitted on a counterweight travelling in tee-section guides is shown in Fig. 142. In this case, one cam is keyed to each end of a connecting camshaft which passes through the counterweight bottom framing. The safety rope passes from the car safety gear over a top pulley, and is then fastened to an operating arm (not shown) keyed to the centre of the counterweight camshaft. Tension on the safety rope causes a pull on the arm which in turn rotates the shaft and brings each cam into contact with its guide, the latter being clamped between the cam and a buffer plate on the counterweight.

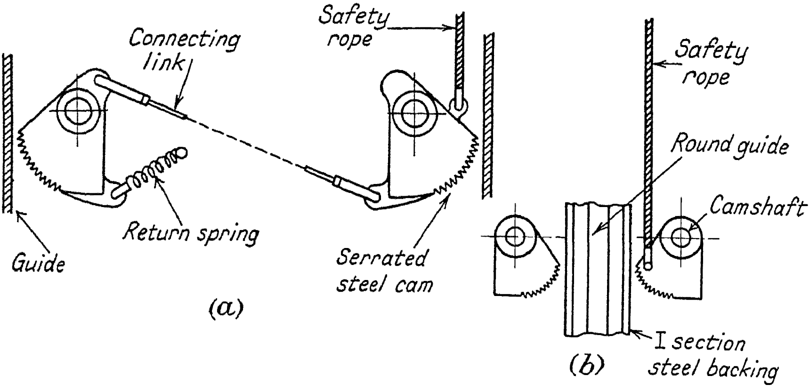


FIG. 141. INSTANTANEOUS CAM TYPE SAFETY GEAR
(*a*) Single type operating on guides (*b*) Double type operating on guide backings

A better type of cam safety gear makes use of two cams on each side of the car, the cams operating on opposite sides of the same guide as in Fig. 143, or on the guide backing, and thus equal pressure is applied in opposite directions to each guide and there is no tendency for the guide to be forced out of the vertical plane. In this type, two connecting camshafts are used, each having a cam keyed at either end. The two shafts are linked together and rotate in opposite directions when the safety rope is pulled. The rope may be fastened to one of the cams as in Fig. 141 (*b*) which shows the cams operating on guide backings or to one of the camshafts, but in either case it is arranged that tension on the rope will cause all four cams to

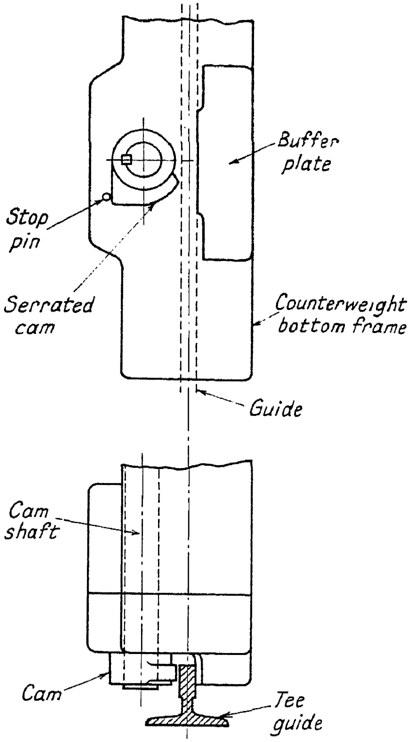


FIG. 142. INSTANTANEOUS CAM SAFETY GEAR, FITTED TO COUNTERWEIGHT

operate simultaneously. The principle of operation of another system of double cams is shown in Fig. 144, although the method of operation in this case is somewhat different from those already described. The gear shown will be brought into operation if either or all of the lifting ropes break or if one of the ropes stretches unduly owing to weakness or to a faulty rope fastening. The sketch illustrates the gear fitted to the top of a counterweight, although it may equally well be employed under the car. Two lifting ropes are attached to a double lever *F* which is free to rotate about its supporting shaft *A*. The safety rope passes from the car safety gear to the counterweight, being attached to the latter at the end of the rope lever *F*. Two operating levers are keyed to each camshaft, the lever arms normally being clear of the rope equalizing lever, which, if the ropes are of equal length, should be in the horizontal position. If both lifting ropes break or stretch unduly, a tension is placed upon the safety rope which causes the equalizing lever to rotate in a clockwise direction, and push upwards the arms of the operating levers *B* and *C*, and these in turn rotate both camshafts and cause the four cams to clamp the guides. A similar result would follow the breaking of rope *Q* alone, whilst if rope *P* broke the cams would be operated by the upward movement of levers *D* and *E*. If either rope stretches unduly, the extra tension placed upon the other rope

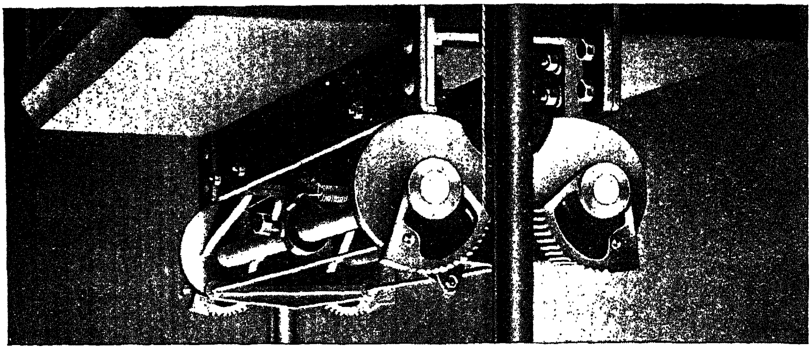


FIG. 143. DOUBLE TYPE INSTANTANEOUS CAM SAFETY GEAR
(*Wm. Wadsworth & Sons*)

would cause the equalizing lever to rotate, and again the cams would be operated.

The methods of operation of the cams which have been described all depend upon the lifting ropes breaking or slackening. The cams, however, may be rotated by connecting the safety rope to an overspeed governor which brings the cams into contact with the guides when a predetermined excess speed in the down direction is reached. By this method the operation of the cams is thus independent of any possible failure of the lifting machine. The action of the governor is described below under gradual wedge clamp gears.

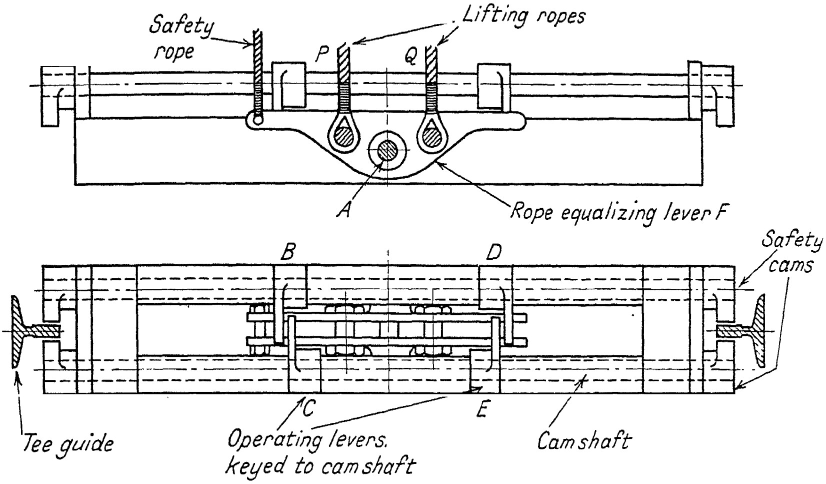


FIG. 144. INSTANTANEOUS CAM SAFETY GEAR

When set, the cams are released from the guides by raising the car, this being done by rotating the motor by hand with the handle usually provided for this purpose.

Gradual Wedge Clamp Safety Gear. On most modern lifts running at speeds in excess of 200 ft. per min., the gradual wedge clamp type safety gear is employed. The clamps exert a gradually increasing retarding force upon the guides, and the car is thus brought to rest smoothly, without fear of damage to the guides or shock to passengers. The gear may be operated on the broken rope principle as described above, but the more

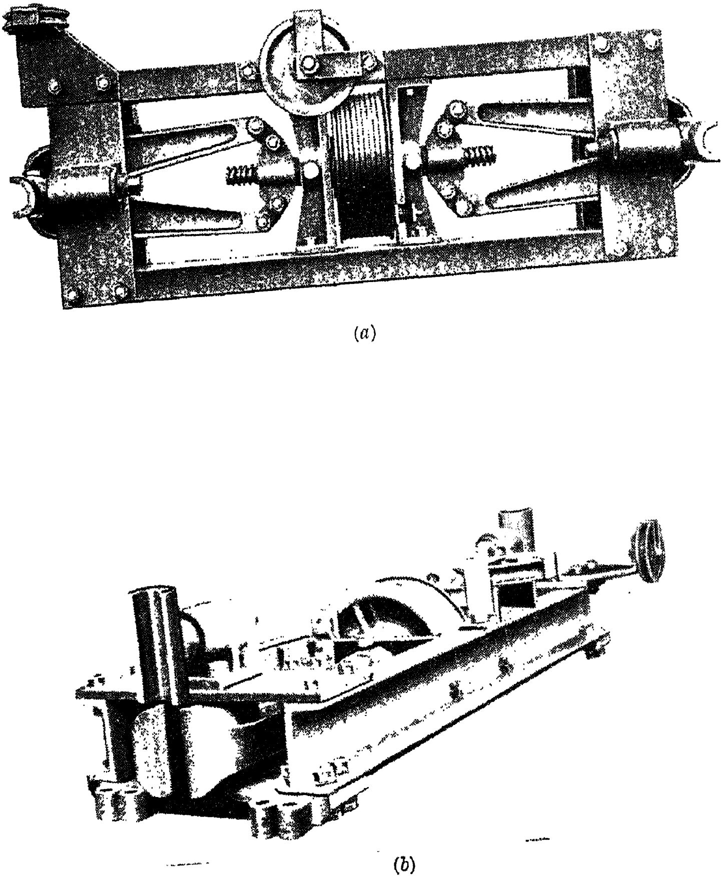


FIG. 145. GRADUAL WEDGE CLAMP SAFETY GEAR

(a) Viewed from below
(b) Viewed from the side

(*Etchells, Congdon & Muir*)

usual method is by means of a speed governor. Two views of safety gear of this type are shown in Fig. 145. The governor rope passes round the governor sheave to a special carrier fitted to the car frame, thence round a weighted pulley in the bottom of the well, and finally back to the governor sheave, as shown in the sketch in Fig. 146. Instead of employing a weighted pulley to ensure a definite drive on the governor sheave, it is sometimes the practice to dispense with this pulley and insert a screw adjustment to give the necessary rope tension. The governor rope is, therefore, driven by the car rope carrier at a speed equal to that of the car, and the speed of rotation of the governor balls or weights, which are driven from the governor sheave, either direct or through gearing, is proportional to that of the car. The safety rope is attached to the governor rope and passes round a drum mounted under the car frame. The diameter of this safety gear drum should not be less than 5 in., and after the safety clamps have operated there should be at least three complete turns of the rope left on the drum. Under normal conditions the carrier grips the governor rope, and when the car speed reaches, say, 10 per cent above the maximum speed, the governor balls have risen sufficiently to operate

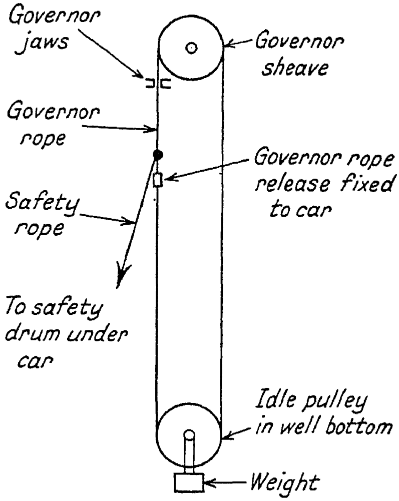


FIG. 146. ARRANGEMENT OF GOVERNOR AND SAFETY ROPES

a switch which cuts off power from the lift and applies the brake. If, however, the speed continues to rise to, say, 20 per cent above the maximum value, the governor balls will rise still higher, and this causes a pair of governor jaws to grip the governor rope. The rope is then jerked free of its carrier and the resulting tension on the safety rope causes the safety drum to revolve. This operates right- and left-handed screws connected to the drum and results in two powerful smooth jaws gripping each car guide and gradually bringing the car to rest. An illustration of the safety gear fitted under a car is in Fig. 147.

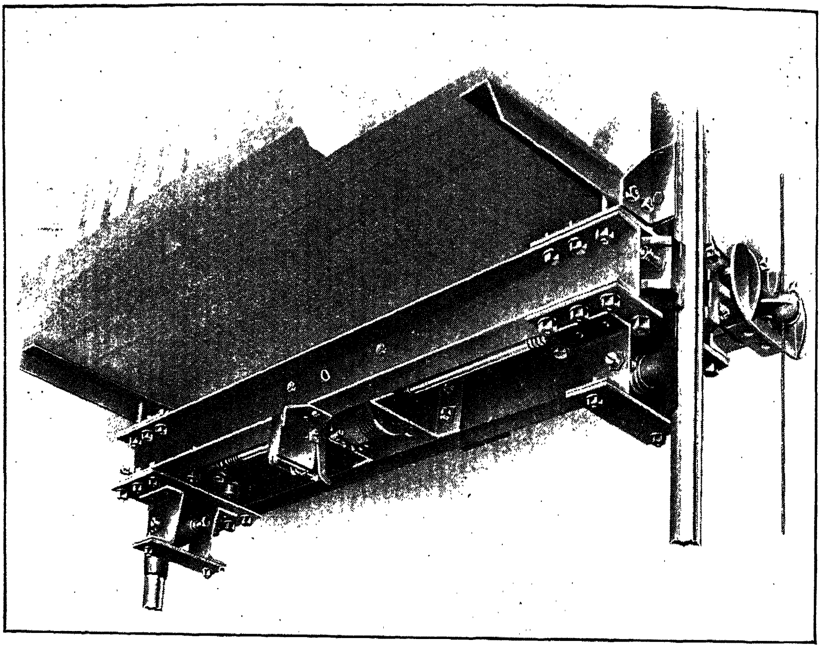


FIG. 147. GRADUAL WEDGE CLAMP SAFETY GEAR FITTED UNDER CAR
(Wm. Wadsworth & Sons)

GOVERNOR ROPE CARRIERS. Several different forms of rope carriers are in use, but the principle is the same in each case. They all perform the functions of attaching the governor rope to the car frame under normal running conditions, and of detaching the rope from the car when the governor jaws grip the rope.

One type is shown in Fig. 148 in which a stop, secured to the rope, is held between two clamps *A* and *B*, these being fixed to the car framework. The top clamp is free to turn upwards and is normally held against the rope stop by the tension of a spring. When the governor jaws set, the pull on the rope rotates the top clamp against the spring tension and the rope stop is jerked free of the carrier.

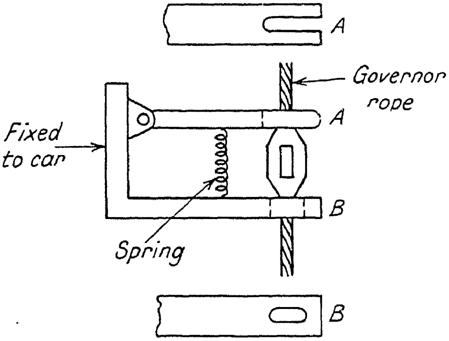


FIG. 148. GOVERNOR ROPE CARRIER

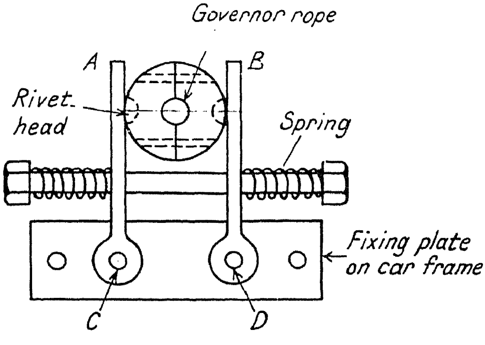


FIG. 149. GOVERNOR ROPE CARRIER

A somewhat similar arrangement is shown in the sketch in Fig. 149. In this, a stop clamped to the governor rope is held between two clamps *A* and *B*, these being pivoted at *C* and *D* respectively. The clamps are attached to a plate secured to the car frame. Two rivet heads on the plates fit into corresponding depressions in the rope stop, and these are held in position by the compression of two springs. Hence, the tension put on the rope when the governor jaws grip, will pull the stop free of the carrier.

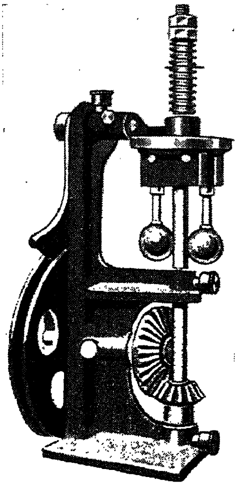


Fig. 150. Vertical Shaft Governor
(Etchells, Congdon & Muir)

Governors. It will be gathered from the foregoing that the object of a governor is to cause the safety gear to operate, if from any cause the speed of the car exceeds its normal maximum speed by more than a certain predetermined value. In addition to operating the safety gear, the governor is generally arranged to cut off the control circuit before or at the same time that the safety gear sets. It is recommended that a governor be fitted to all power-driven lifts which have travels in excess of 18 ft. Car speed governors should be set so as to cause the application of the safety gear at a speed not more than 40 per cent and not less than 15 per cent above the maximum speed, but no governor should be required to trip at a speed less than 175 ft. per min., and with the instantaneous cam type gear, should trip at a speed not above 250 ft. per min. If counterweight safety gear is provided, this may be operated by the same governor and governor rope used to operate the car safety gear. Provision is often made to cause the counterweight gear to be applied at a speed in excess (not more than 10 per cent) of that at which the car safety gear applies. The governor ropes should run free of the governor jaws during normal operation of the lift, and it is recommended that the governor gears have self-lubricating bearings which do not require frequent attention. The machine room is probably the best, and is certainly the most usual, location for the governor. Several different types of overspeed governors are available for lifts, but they are almost all of the centrifugal pattern, having either a vertical or horizontal governor shaft.

A geared vertical shaft governor is shown in Fig. 150 with the governor rope, sheave, and gripping jaw on the left-hand side. As the car speed increases, the balls open and raise the operating plate against the spring tension. When the predetermined excess speed is attained, the plate turns the lever and causes the jaw to grip the rope.

Fig. 151 illustrates a governor of the horizontal shaft pattern with the weights secured to the governor sheave and revolving in a vertical plane. As the speed rises, the rotating diameter of the weights increases due to centrifugal force operating against the pull of two equalizing springs. When a speed of, say, 10 per cent, in excess of the maximum speed is attained, the weights open the control switch shown at the right of the illustration, and thus cut off the control circuit. If the speed continues to rise to, say, 20 per cent above the maximum speed, the weights open still further, and release the pawl which normally holds the governor jaws clear of the governor rope.

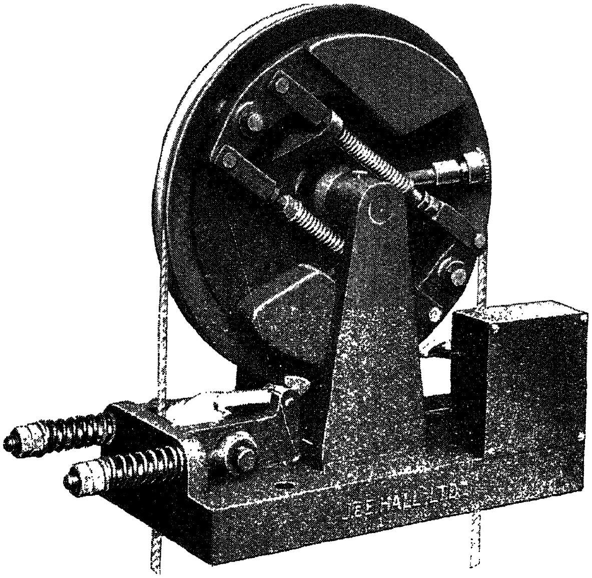


FIG. 151. AUTOMATIC SPEED GOVERNOR AND SWITCH
(*J. & E. Hall, Ltd.*)

The tension of the two springs at the left-hand side of the illustration then pulls the jaws into contact with the rope and causes the safety gear to operate.

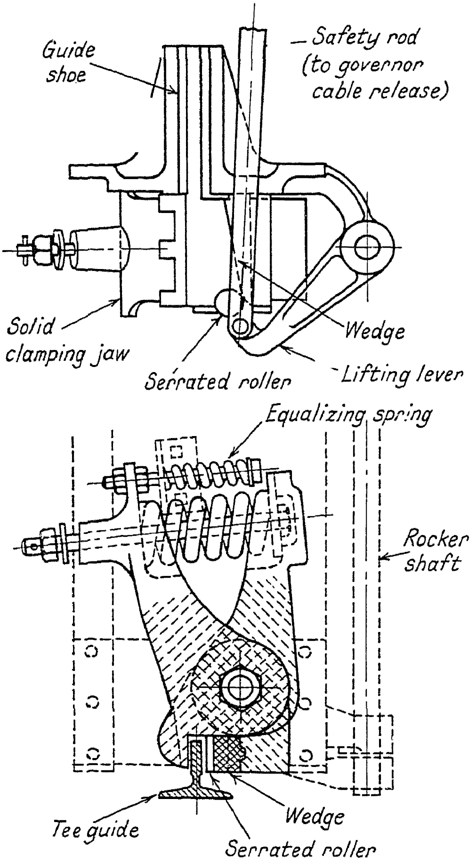


FIG. 152. FLEXIBLE GUIDE CLAMP SAFETY GEAR

Flexible Guide Clamp Safety Gear. A further type of safety gear, known as the *flexible guide clamp* gear, is sometimes employed on high-speed lifts, and, when operated, applies a constant retarding force to the car motion. A sketch showing the principle of Messrs. Waygood Otis' gear of this pattern is shown in Fig. 152. The retarding force is obtained by clamping the guide between a roller and a steel jaw, with a predetermined clamping force. This force is obtained by a strong compression spring fitted at the back of the clamping jaws, the latter being pivoted on pins and extending on each side of the guide. One jaw forms a solid shoe which is brought into direct contact with the guide when the safety gear acts. The opposite jaw forms a housing for the serrated roller and a steel wedge which is placed above the roller with its inclined plane towards the guide. The wedge is free to swivel in the jaw so that its surface is always parallel with that of the guide. The rollers are actuated by levers which are placed directly under the rollers and keyed to a rocker shaft passing beneath the car platform. The shaft connects the two sets of safety gear on opposite sides of the car. One end of the lifting rod is connected to one of the levers, and the other end to the governor rope releasing device, mounted on the car frame. The governor is fitted at the top of the well. When a predetermined excessive car speed is reached, the governor rope is gripped by the governor jaws, the lifting rod pulled up, and the two levers then push their rollers up between the guides and the inclined plane of their respective wedges. The rollers, on meeting the guides, still continue their upward motion, pushing the wedges away from the guides and thereby causing the jaws to rotate slightly upon their pins. The solid jaw first comes into contact with the guide, after which the jaw forming the housing for the wedge, still receding from the guide, compresses the spring between the rear ends of the two jaws. When the roller comes to its final stop against the stop plate provided, the spring will have compressed a definite amount, which, by means of the leverage of the jaws, will give a known clamping and retarding force on the guides. When the safety gear is out of operation, the rollers are held away from the guides by a small bracket bolted under the wedge jaw, and at the same time the jaws are held away from the guide by the small equalizing spring at the back end of the jaws. This spring is arranged to force the jaws over against the wedge stop plate.

Safety Gear Stopping Distances. The stopping distance with the instantaneous cam type safety gear is very small and seldom exceeds two or three inches, but the stopping distances

Speed (ft. per min.)	Maximum Distance with Full Load		Minimum Distance with Attendant only in the Car	
	Type G.W.C.	Type F.G.C.	Type G.W.C.	Type F.G.C.
	ft. in.	ft. in.	ft. in.	ft. in.
300	7 0	1 9	1 6	0 6
400	7 9	2 6	1 8	0 9
500	8 9	3 6	1 10	1 0
600	10 0	4 9	2 1	1 3
700	11 3	6 6	2 4	1 6
800	12 3	8 3	2 8	1 9

of the gradual wedge clamp (G.W.C.) and flexible guide clamp (F.G.C.) types are much greater and these gears are adjusted so that the distance varies with the car speed. The maximum stopping distances of cars with safety gears of types G.W.C. and F.G.C., with the maximum load in the car, and the minimum stopping distances with the attendant only in the car, should be as given in the table on page 175.*

Stopping distance means the actual slide, as measured by the marks on the guides.

Car and Counterweight Clearances. Clearances must be allowed for the car at the top and bottom of the well so as to permit it to slow down if, for any reason, a terminal floor is over-run and the ultimate limit switch is operated. Suitable top and bottom clearances must also be provided for the counterweight.

The top car clearance is the distance between the uppermost part of the car or any rigid attachment thereto and the nearest fouling point of the overhead structure, when the car is level with the top landing.

The bottom car clearance is the distance, including the buffer compression, between the lowermost part of the car or any rigid attachment and the top of the car buffers, when the car is level with the bottom landing.

The top counterweight clearance is the shortest vertical distance between any part of the counterweight assembly and the nearest part of the overhead structure, when the car is level with the bottom landing.

The bottom counterweight clearance is the shortest vertical distance between any part of the counterweight assembly and any fixed obstruction below it, when the car is level with the top landing.

The clearances allowed, in practice, depend upon the maximum car speed and type of drive, but they should never be less than those shown in the table on page 177.†

To ensure that the counterweight does not foul the overhead structure when the car is resting on its buffers, the top counterweight clearance should be 6 in. greater than the bottom car

---

* *Code of Practice for the Installation of Lifts* (Building Industries National Council).

† *Ibid.*

Minimum Clearances for Cars and Counterweights

Maximum Speed (ft. per min.)	Top Clearance		Bottom Clearance		
	Car		Counterweight		Car
	Traction	Drum	Traction	Drum	Traction and Drum
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
0–80	1 6	2 6	1 0	2 0	1 6
81–125	2 0	3 0	1 0	2 0	1 6
126–200	3 0	4 0	1 6	3 0	2 0
201–300	4 0	5 4	2 0	4 0	2 6
301–400	5 0		2 6		2 9
401–500	6 0		3 0		3 3
501–600	7 0		3 6		3 9
601–700	8 0		4 0		4 3
701–800	9 6		4 9		4 9

clearance for speeds up to 250 ft. per min., and 9 in. greater for speeds of over 250 ft. per min. For a service lift (goods only) the top clearance should be not less than 1 ft. 6 in. for a traction drive, and not less than 2 ft. for a drum drive, whilst the bottom clearance should be not less than 1 ft. 6 in.

The top overtravel is defined as the distance provided for the car floor to travel above the level of the top terminal landing before the car is stopped by the ultimate limit switch.

The bottom overtravel is the distance the car floor can travel below the level of the bottom landing before the car is stopped by the ultimate limit switch.

LIMIT SWITCHES

Terminal Limit Switches. Every electric lift should be provided with an upper and a lower terminal limit switch, these being arranged to stop the car automatically within the top and bottom overtravels, from the normal maximum speed. These switches act independently of the normal operating device, the ultimate or final limit switches, and the buffers. They may be fitted to the car and operated by a ramp in the well, or in the well and operated by a car ramp. Alternatively, the switches may be fitted in the motor room, but in all three cases they must be operated by the movement of the car. In

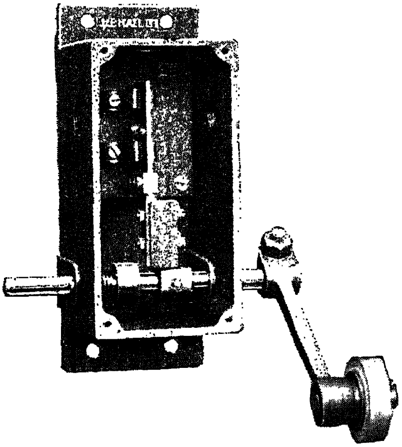


FIG. 153. TERMINAL LIMIT SWITCH
(Cover removed)
(*J. & E. Hall, Ltd.*)

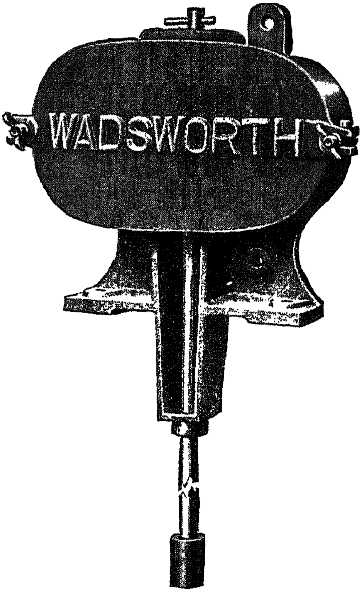


FIG. 154. TERMINAL LIMIT SWITCH
(*Wm. Wadsworth & Sons*)

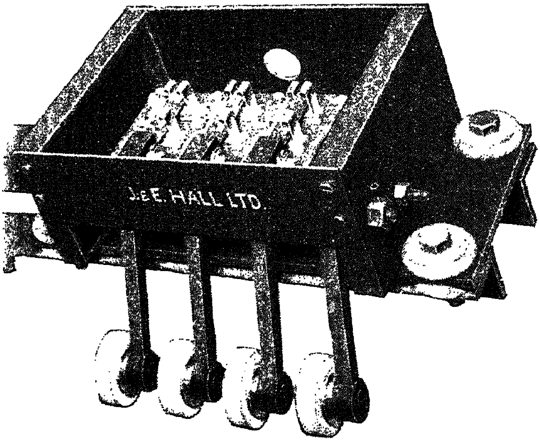


FIG. 155. MULTIPLE SLOWING SWITCH
(With cover removed)
(*J. & E. Hall, Ltd.*)

some switches the contacts are of the knife pattern and, in others, of the plate contactor type.

A terminal limit switch of the knife pattern for cutting off the control circuit and suitable for well or car mounting is shown in Fig. 153.

Fig. 154 depicts a terminal limit switch arranged for mounting in the machine room.

On high-speed lifts it is usual to install slowing limit switches which automatically reduce the speed of the car before the terminals are reached. The slowing down is accomplished by means of a multiple slowing switch, the contacts of which are opened

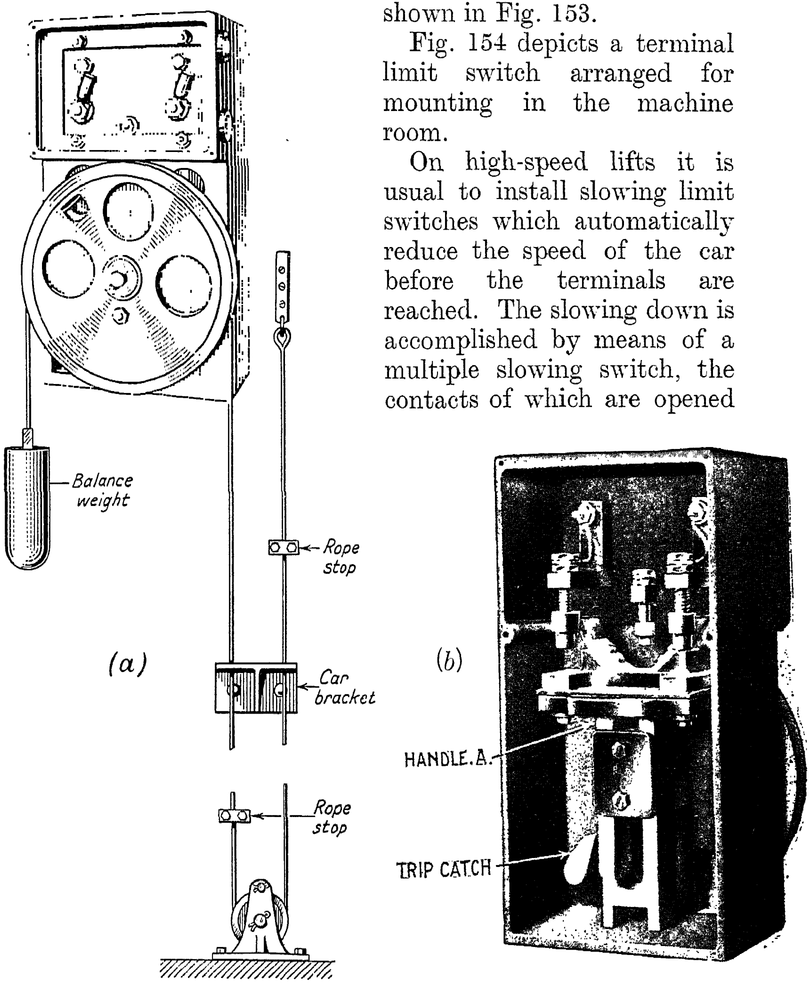


Fig. 156. Final Limit Switch

(a) General arrangement (b) Interior of switchbox

(*Wm. Wadsworth & Sons*)

by ramps fitted in the well. An example of a switch of this type is shown in Fig. 155.

Ultimate or Final Limit Switches. These are arranged to stop the car automatically within the top and bottom clearances, independently of the normal operating device and the terminal limit switches, but with the buffers operative. The switches and the oil buffer should be so arranged that the opening of the switch and engagement of the buffer are as nearly simultaneous as possible. With spring buffers, however, the switch should open before the buffers are engaged. After operating, these switches remain open until the car has been moved by hand winding to a position within the limits of normal travel. Ultimate or final limit switches should not be mounted on the car, the usual position being in the machine room, and they are operated by the movement of the car in the well. The general practice is for the ultimate limit switch to open simultaneously both the control and motor circuits.

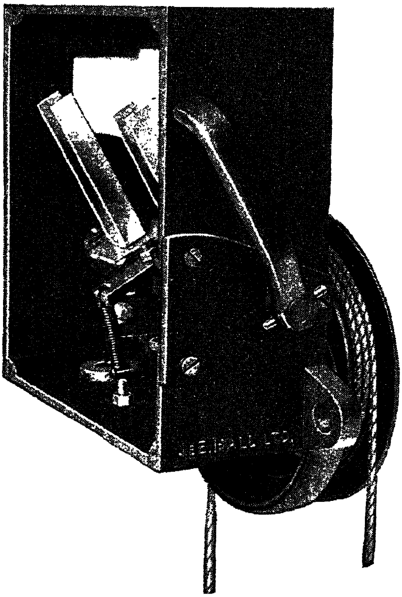


FIG. 157. FINAL LIMIT SWITCH
(Cover removed)
(*J. & E. Hall, Ltd.*)

The usual method of operation is shown in Fig. 156. A steel flyrope, passing around the switch operating drum, is anchored in the machine room at one end and has a balance weight attached to the other end. Rope stops are secured to this rope at the top and bottom limits of travel, and a bracket, fixed to the car, slides freely over the rope. When the car bracket comes into contact with either rope stop, the drum is rotated and the switch opened. A final limit switch of the knife pattern is shown in Fig. 157.

BUFFERS

In the event of the limit switches failing to operate, and the car not coming to rest within the clearance provided, either the car or counterweight will make contact with buffers which lessen the impact. Two buffers are fitted in the well under the car, these being placed symmetrically with respect to the centre of gravity of the car, and, in addition, one or two buffers are fitted under the counterweight. These buffers therefore constitute the final emergency device.

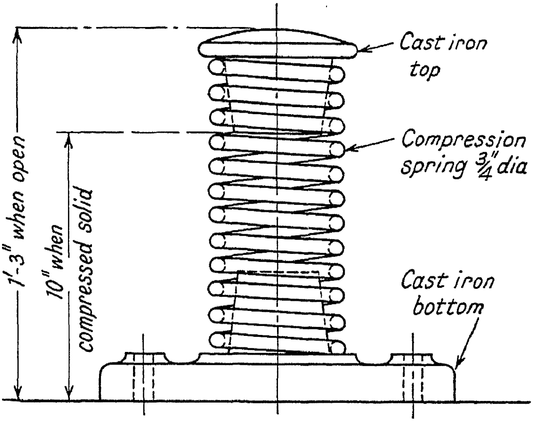


FIG. 158. SPIRAL SPRING BUFFER

Spring Buffers. For speeds up to 300 ft. per min. buffers may consist of helical springs of the type shown in the sketch in Fig. 158; or volute springs, an example of which is reproduced in Fig. 159.

Oil Buffers. These are fitted for car speeds above 300 ft. per min., the piston stroke depending upon the maximum car speed. The minimum total stroke is calculated upon an average retardation of 32·2 ft. per sec. per sec., based on the governor tripping speed. The maximum retardation, based on governor tripping speed, should not exceed 80·5 ft. per sec. per sec., i.e. $2\frac{1}{2}$ times the retardation due to gravity.

SPRING RETURN OIL BUFFER. The oil buffer usually employed for lift cars is of the spring return type. The following is a brief description of Messrs. Waygood Otis' spring return oil buffer, a drawing of which is shown in Fig. 160. When the car strikes the buffer, a spring in the upper part of the piston rod is compressed, and acts as a cushion for the rod and piston, thus preventing them receiving a too sudden blow. A rubber cushion, at the top of the buffer, also further deadens the blow. As the piston starts its downward movement, the oil beneath it is forced from the cylinder into the outer casing, and also into the upper chamber, through a series of holes in the cylinder. The area of the upper holes is large, and therefore little resistance is offered to the flow of oil during the initial piston movement. Hence, the piston accelerates fairly rapidly and takes up the running speed of the car. Any back pressure due to the inertia of the piston and rod in starting is absorbed by the spring. As the piston descends, the number and size of the holes below the piston become less and the restriction to the oil flow increases. When the piston has closed the last hole the car comes to rest.

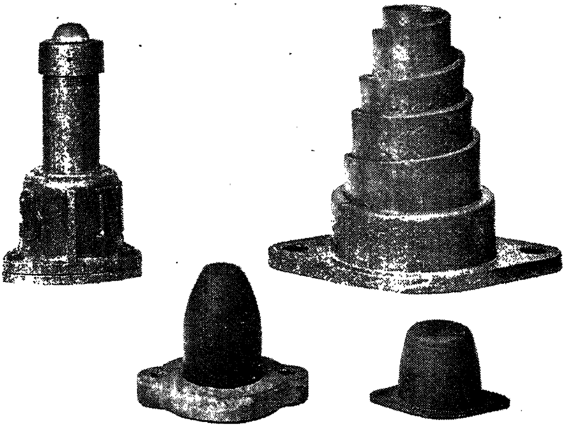


FIG. 159. TYPES OF BUFFERS
(*Marryat & Scott*)

As soon as the car is moved away, the piston is forced upwards by the large spring, and the moving parts restored to their normal position, whilst at the same time the oil flows

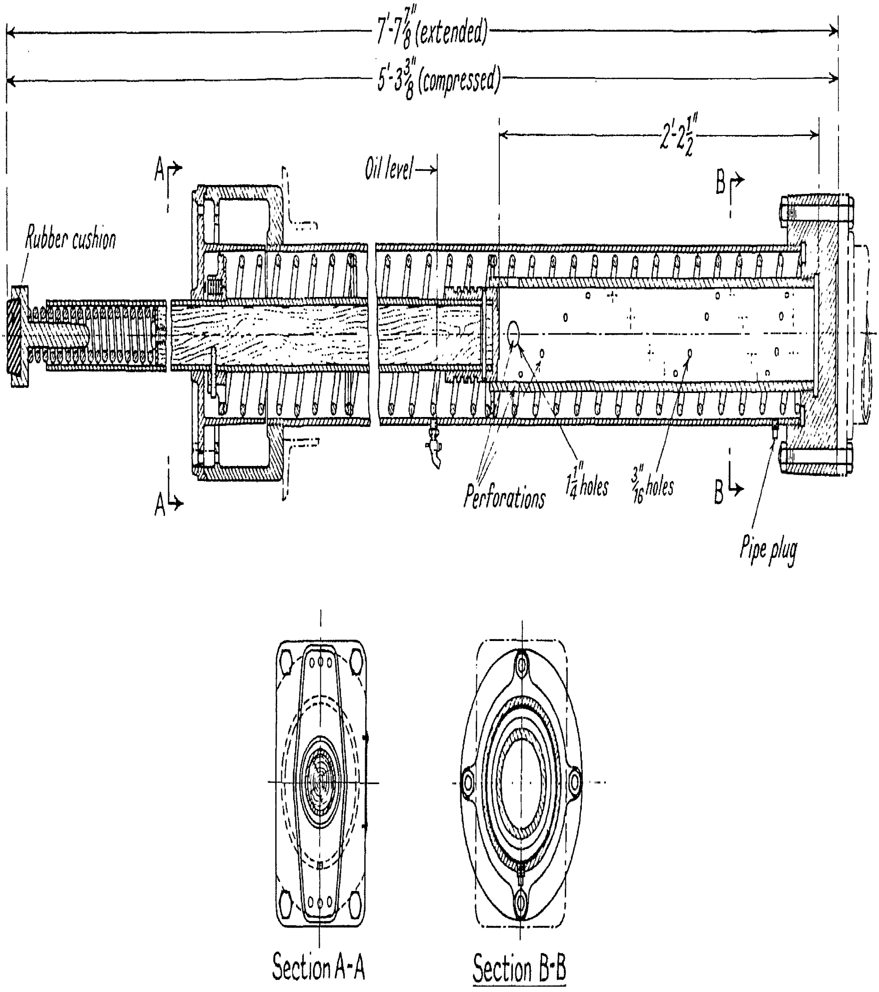


Fig. 160. Spring Return Oil Buffer

28 in. stroke

(Waygood Otis, Ltd.)

back into the cylinder. An illustration of a buffer of this type is shown in Fig. 161.

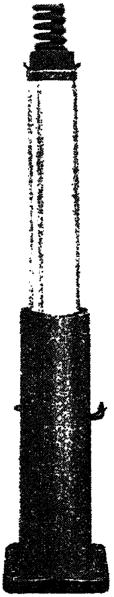


FIG. 161. OIL BUFFER
(*J. & E. Hall, Ltd.*)

GRAVITY RETURN OIL BUFFER. The following description relates to Messrs. Waygood Otis' oil buffer, shown in Fig. 162. This type is generally used as a counterweight buffer, as it can be attached to the bottom of the counterweight and so form a useful part of the counterweight itself. The cylinder consists of upper and lower oil chambers, and when the buffer is stopped by striking a block at the bottom of the well, the oil contained in the lower chamber is forced into the upper one, through an area formed by longitudinal slots in the plunger and its guiding sleeve. These slots are of varying lengths and so arranged as to provide a reasonably constant retardation of the moving counterweight. By the time the longest slot is covered in the sleeve, the energy of the counterweight has been entirely absorbed. Any further downward movement of the plunger is prevented since the oil has no additional outlet. The cover of the upper oil chamber is provided with baffles to avoid the oil being sprayed out when the buffer is in operation.

Car Emergency Handle. The gearing on some geared lifts is cut so that its efficiency is low and the lift itself is self-sustaining. This is an important safeguard, as even if the main brake fails to hold the lift for any reason it is unlikely that the

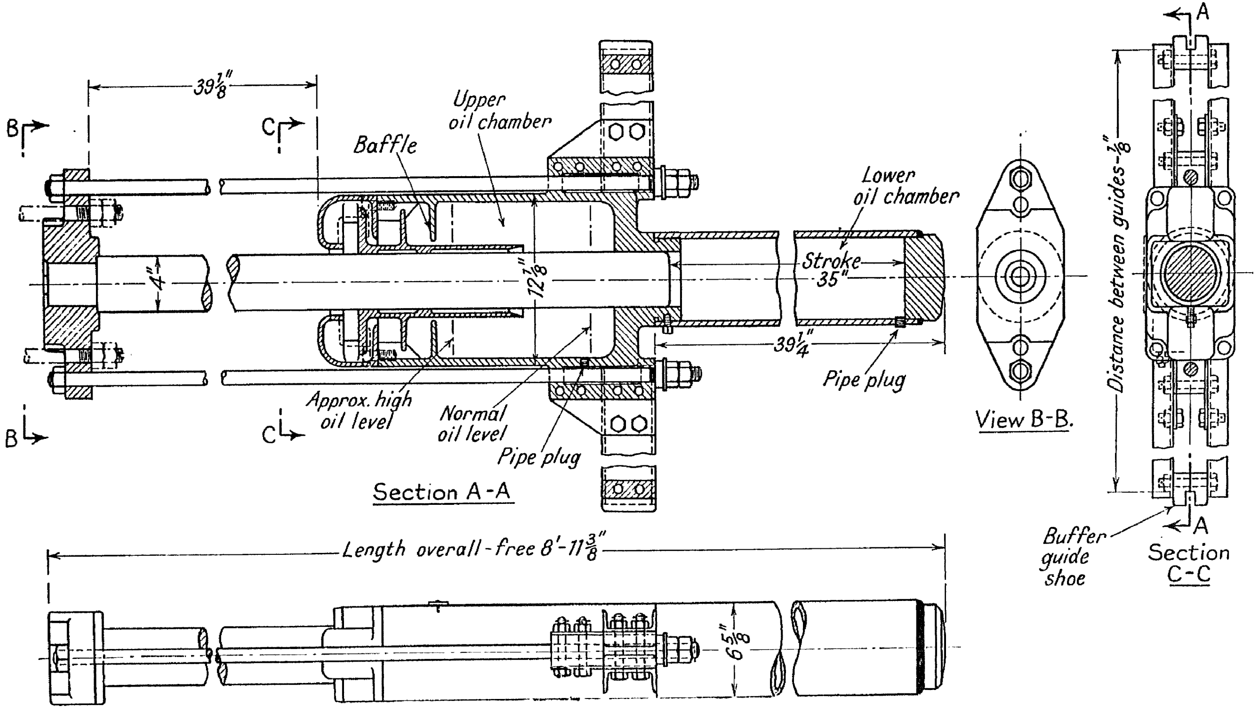


FIG. 162. GRAVITY RETURN OIL BUFFER
35 in. stroke
(*Waygood Otis, Ltd.*)

lift will "run away" because of the irreversibility of the gearing. High efficiency geared lifts and gearless lifts, however, are not self-sustaining, and in order to counteract, somewhat, the loss of this safety feature, a handle is frequently fitted in the car, the pulling or turning of which will disconnect the lift supply, usually by causing a pull on the final limit rope, and in addition operate the brake mechanically, by means independent of the normal method of operation. This emergency handle, when operated, sometimes causes a heavy weight to fall and this weight, being fitted to the brake shoes by a system of levers, thus operates the shoes and applies the brake. Emergency gear fitted to the main brake in this manner is liable to interfere with accurate floor levelling, and to obviate this the emergency brake sometimes consists of a brake and drum unit entirely separate from the main brake.

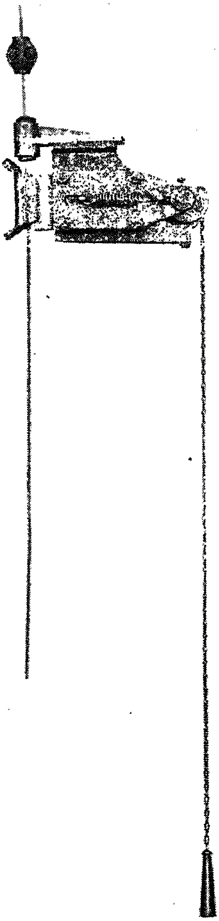


FIG. 163. CAR EMERGENCY HANDLE
(*Marryat & Scott*)

In another system, the handle is so arranged that when operated it pulls on the final limit rope and so cuts off the lift supply, and simultaneously completely disconnects the brake solenoid (mechanically) from the shoes, thus leaving the springs free to operate the brake in the normal manner. This eliminates possible danger due to any fault in the control circuit or in the brake solenoid plunger, either of which might cause the brake to be held in the off position. A typical emergency handle for gripping the final limit rope is shown in Fig. 163.

CHAPTER XIII

FLOOR LEVELLING SYSTEMS

ACCURATE levelling of the car at the various landings is an essential to good lift service; with passenger lifts the danger of passengers tripping when entering or leaving the car must be minimized, whilst with goods lifts, particularly if trucks or trolleys are carried, easy entry and exit are desirable. Inaccurate levelling also results in "inching" of the car to obtain better final levelling, and a consequent increase in energy consumption and wear on the controller contacts. A method used to counteract the difficulties due to minor inaccuracies in floor levelling, without actually re-levelling the car, is shown in Fig. 164. This hinged ramp greatly facilitates the passage of small-wheeled trucks by bridging over the bottom car and landing gate tracks and the gap normally existing between the landing sill and the car floor. It can also be seen how the ramp forms a toe-guard when the gate is closed.

With simple car switch control, stopping is performed by the operator returning the car switch to the centre position when the car is at the appropriate distance from the floor. The centring of the car switch cuts off the supply and causes the brake to operate, in the case of a single-speed lift; but if a two-speed motor is employed, an intermediate car switch position enables the final stopping to be performed from slow speed. The accuracy of levelling therefore depends upon the judgment of the operator in returning the switch to the slow and stop positions at the correct moments. In some forms of car switch control, stopping is performed automatically by centring the car switch when the car has passed the floor immediately preceding that at which a stop is desired. The levelling, in these cases, is dependent upon the settings of the automatic slowing and stopping devices, and the adjustment of the mechanical brake.

Several methods are employed to stop an automatic lift at the desired landing, the efficiency of the schemes depending upon the accuracy of timing of the automatic slowing and stopping devices in reducing the car speed and cutting off the motor supply respectively before the operation of the mechanical brake.

Besides good brake adjustment and accuracy of setting of the slowing and stopping equipment, another factor which affects levelling is the variation of load in the car. Some small consideration will show that the distance required for the stopping of the car, after the application of the brake, will be greater if full load is being lowered than with an empty car, on the assumption that the brake retarding force is the same in each case. Similarly, the distance in which the car will come to rest when raising full load is less than when raising an empty car. To ensure good levelling it is essential that the distances travelled by the car after the application of the brake should be the same, irrespective of load, and to effect this it is desirable to arrange that the final cut-off speed of the car is slightly

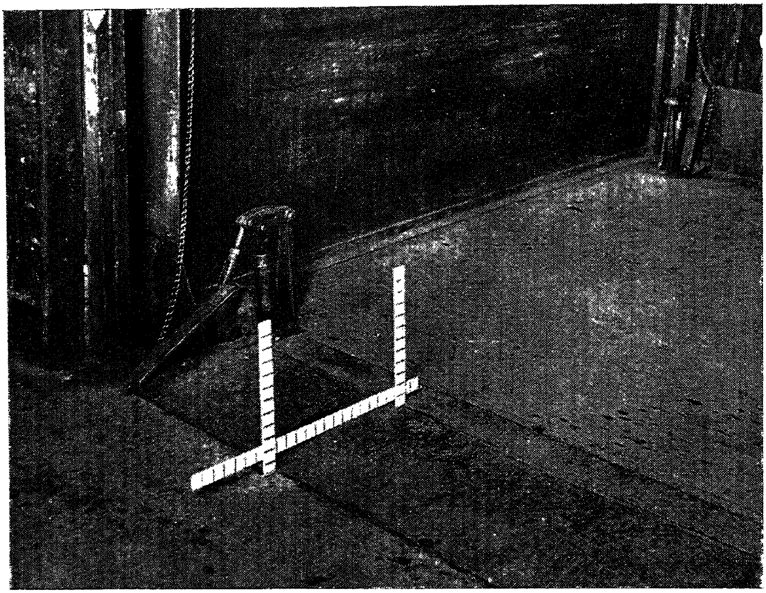


FIG. 164. CAR LEVELLING RAMP
(Marryat & Scott)

higher when lifting full load than when lifting an empty car. In other words, the speed should slightly increase with the load, and this means a rising motor characteristic. This characteristic, whilst unstable with an ordinary shunt machine, may readily be obtained with variable voltage control. The rising characteristic is only required at the slow levelling speed, which is from about one-sixth to one-tenth of the maximum speed.

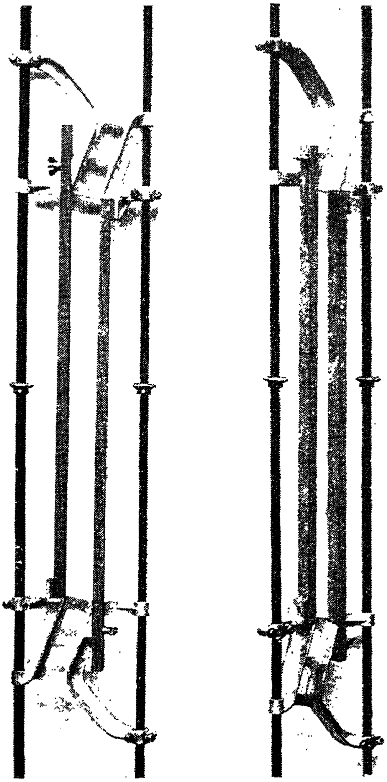


FIG. 165. DIRECTION SWITCH RAMP
(*Marryat & Scott*)

The principal methods used for automatically slowing, stopping, and levelling lift cars are described below.

Direction Switches. Direction switches, sometimes used on single-speed automatic lifts, are either single- or two-way switches fitted in the well, one at each landing. A two-way switch is necessary for each intermediate landing (one way for each direction of travel) but a single-way switch only is required at each terminal landing. Each switch is operated by a ramp, fitted to the car, when the car reaches the appropriate landing. When passing landings in the upward direction, the switches are in turn operated, and thereby change the floor relay connexions from the UP contactor to the DOWN coil ready for operation during the down direction. Hence each direction switch which is below the car is connected to the DOWN contactor coil. Similarly, during the downward travel the ramp moves the switch operating arms to the up direction, and therefore all direction switches above the car are joined to the UP contactor coil. When the car is stationary at a landing the corresponding direction switch is in the centre or OFF position, and current is thus cut off from the main contactor coil. Each terminal direction switch is opened and closed when the car arrives at and leaves the terminal landing respectively. A typical operating ramp is shown in Fig. 165, the top throw-in horn engaging the switch arm roller during the upward journey, and the bottom horn returning the roller to its original position during the downward journey. When the roller is in contact with the centre vertical track, both contacts of the switch are disconnected. An intermediate floor direction switch is shown in Fig. 166.

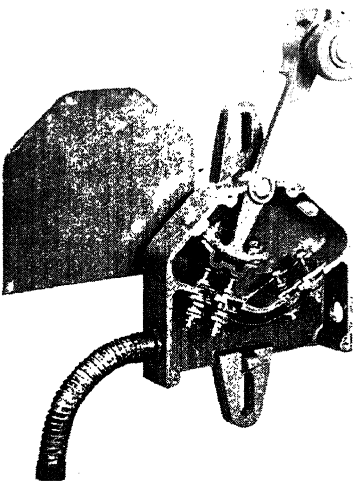


FIG. 166. DIRECTION SWITCH
(Intermediate floor)
(*Marryat & Scott*)

Floor Selectors. A floor selector switch for installation in the motor room, as shown in Fig. 167, is frequently used to perform the functions of slowing and stopping. The slowing and stopping contactor coils are controlled by a system of contacts operated by selector arms fixed to a shaft, on one end of which is keyed a drum, the drum being driven from the car by a steel flyrope. Hence the selector arms rotate in unison with the movement of the car in the well, and open-circuit the slowing and stopping contactor coils when the car is at the appropriate positions in the well. For each intermediate floor served, two switches and two operating arms are required for stopping in the two directions, whilst only one switch and one arm are necessary for each terminal floor. With two-speed motors, additional switches and selector arms are necessary for each floor so as to perform the slowing down prior to the operation of the stopping switches.

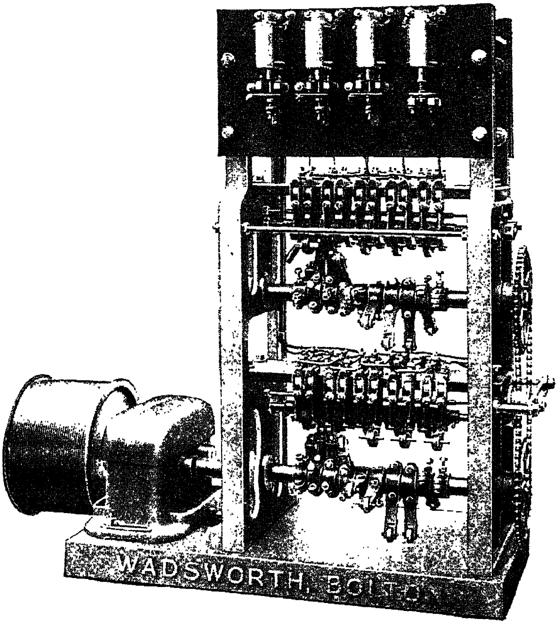


FIG. 167. FLOOR SELECTOR FOR AUTOMATIC LIFT
(Wm. Wadsworth & Sons)

Another type of floor selector for installation in the motor room is shown in Fig. 168 and consists of two copper drums insulated from one another. These drums are rotated by the motion of the car, being driven through gearing from a pulley which is connected to the car by means of a flat steel tape. In addition to their circumferential movement, the drums rotate on a screw which causes them to travel in the vertical direction. The result is that a high degree of accuracy is obtained, a movement of about $\frac{1}{4}$ in. on the drum being obtained for every 1 in. travel of the car. For tall buildings, the dimensions of the selector increase vertically and not horizontally, and for ten floors and two speeds the height is about 4 ft.

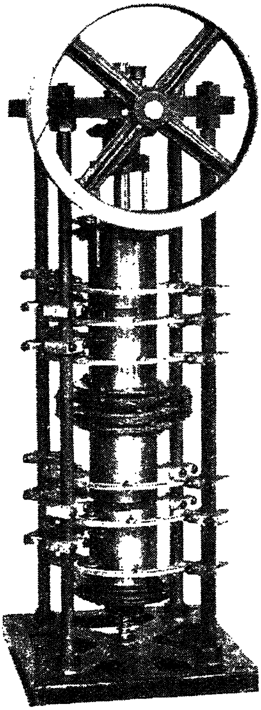


FIG. 168. TWO-SPEED DRUM TYPE FLOOR SELECTOR
(*Etchells, Congdon & Muir*)

Corrective Levelling Systems. Various means have been adopted for securing accurate final levelling in which the levelling resulting from the operation of the floor selector stopping switches is corrected, if necessary, by independent means. With some of these corrective levelling devices it is possible to secure final levelling to within $\pm\frac{1}{8}$ in., irrespective of load variations or rope stretch during loading.

In a method employed by Messrs. Wm. Wadsworth & Sons, a three-level ramp is fitted at each landing, this ramp engaging a three-position switch fitted to the car, at those landings where stops are made. If the car stops below the landing, after the floor selector switch has operated in the normal manner, the three-position switch will engage with the bottom level of the ramp. This results in the motor being re-started and run at the slow speed, in such a direction that the car travels upwards. When the switch engages with the centre level the car is correctly levelled, the motor supply is cut off and the brake applied. Similarly, if the levelling is too high, the switch on the car engages with the top ramp level and this causes the motor to run at slow speed in the opposite direction and the car thus travels downwards until the centre cam level engages the switch, when the motor supply is cut off and the brake applied. The levelling switch, which is automatically withdrawn beyond reach of the ramp when passing landings, is of special construction and correctly engages the ramp irrespective of any car side movement due to shoe wear.

THE MICRO DRIVE. This corrective levelling scheme, designed and manufactured by Messrs. Waygood Otis, employs a separate small motor which effects the final levelling at a slow speed, the principle of operation consisting essentially of bringing the car to rest with a normal floor selector, and then correcting any inaccuracy in the levelling. The micro gear (Fig. 169) comprises a small motor, brake and worm reduction gear operated from a controller incorporated in the main controller. The main brake is of the usual type and may be operated by an electromagnet or a torque motor, but the brake housing is fastened to the worm-wheel shaft of the micro gear and revolves with it. During normal running and stopping, the brake functions in the usual manner to stop the main machine, but when the micro gear operates, the main brake acts as a friction clutch for the micro machine to drive the main machine. After the main controller has cut off the main motor supply in the normal manner, the micro controller is operated by a levelling switch on the car, if the levelling is incorrect. This switch incorporates two sets of contacts, one for the up direction and the other for the down direction, these contacts being operated by two roller arms, shown in Fig. 170. Two cams *R* and *S* are fitted in the well at each landing, the former cam operating roller *P* and closing the up direction contacts of the levelling switch, thus causing the micro motor to move the lift upwards at a slow speed. Cam *S* similarly causes the micro motor to rotate in the opposite direction and move the car downwards when it comes into contact with roller *Q*. The

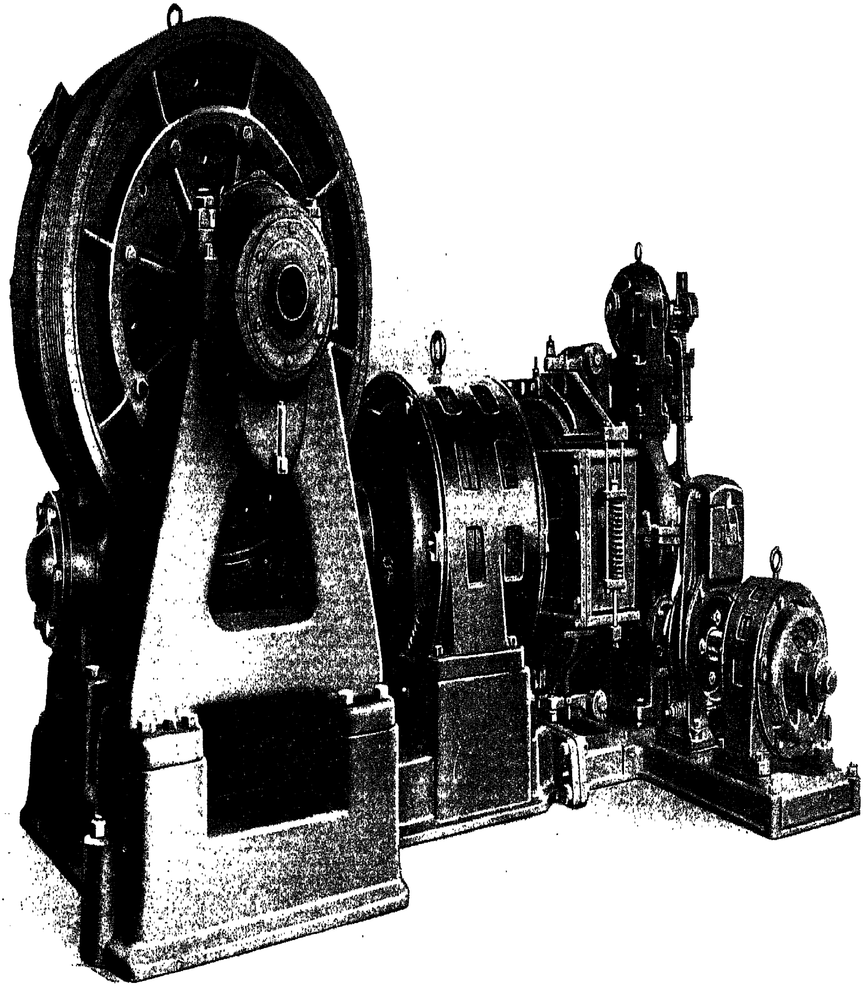
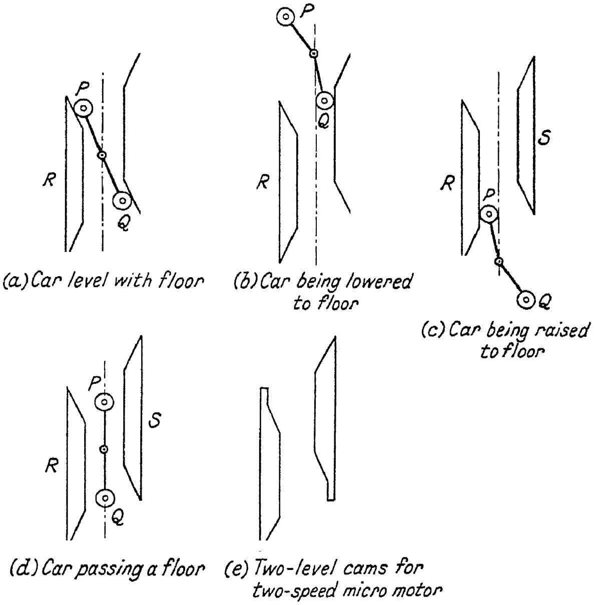


FIG. 169. SINGLE-WRAP TRACTION LIFT MACHINE

With auxiliary micro drive

(*Waygood Otis, Ltd.*)

various positions of the levelling switch are also shown in Fig. 170. At position (*a*) the car is correctly levelled, both contacts of the levelling switch are open, and the micro motor stationary. The position of the levelling switch at (*b*) is that taken up when the car has stopped too high. Roller *Q* is in contact with cam *S* and the down contacts of the levelling switch are closed. At (*c*) the car has stopped too low and roller *P* has closed the up contacts of the levelling switch. When passing a landing, the arms are electromagnetically withdrawn to the vertical position shown at (*d*) and they are thus beyond reach of the cams and the micro motor is cut off. When a two-speed micro motor is employed, the cams have two levels, as shown at (*e*), and the levelling switch additional contacts for operating the motor at its two speeds.



(*a*) Car level with floor (*b*) Car being lowered to floor (*c*) Car being raised to floor

(*d*) Car passing a floor (*e*) Two-level cams for two-speed micro motor

FIG. 170. LEVELLING SWITCH AND CAMS FOR MICRO DRIVE

The micro drive ensures that levelling is automatically accomplished, irrespective of load or speed, and accurate levelling is maintained regardless of rope stretch or change of load. The gear can be built for any load and speed and for car switch or automatic control.

THE "LEVELTRIC" SYSTEM. Messrs. Marryat & Scott's patent "Leveltric" system* of levelling shown in Fig. 171 also incorporates a small auxiliary motor which performs the final levelling at slow speed. The main motor drives the lift through gearing in the ordinary way, the auxiliary motor being mounted on the main motor and connected to the main motor shaft by a silent chain drive giving a speed reduction of about 10 to 1, and a specially constructed speed-operated clutch. The connexions between the main and auxiliary motors, with the clutch on the left, are shown in Fig. 172. The clutch either connects the auxiliary motor to, or disconnects it from, the

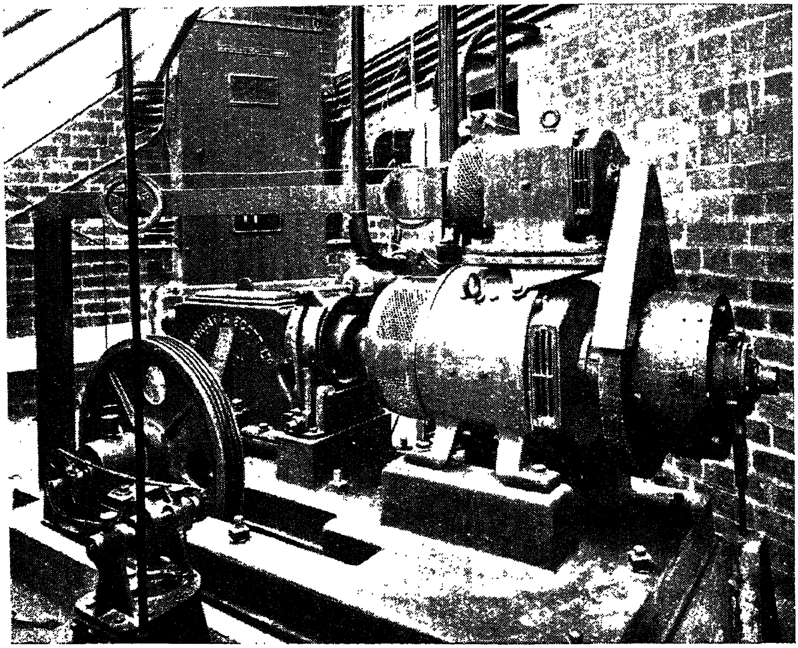


FIG. 171. LIFT MACHINE WITH "LEVELTRIC" EQUIPMENT
(*Marryat & Scott*)

---

* See *Engineering*, 12th December, 1930.

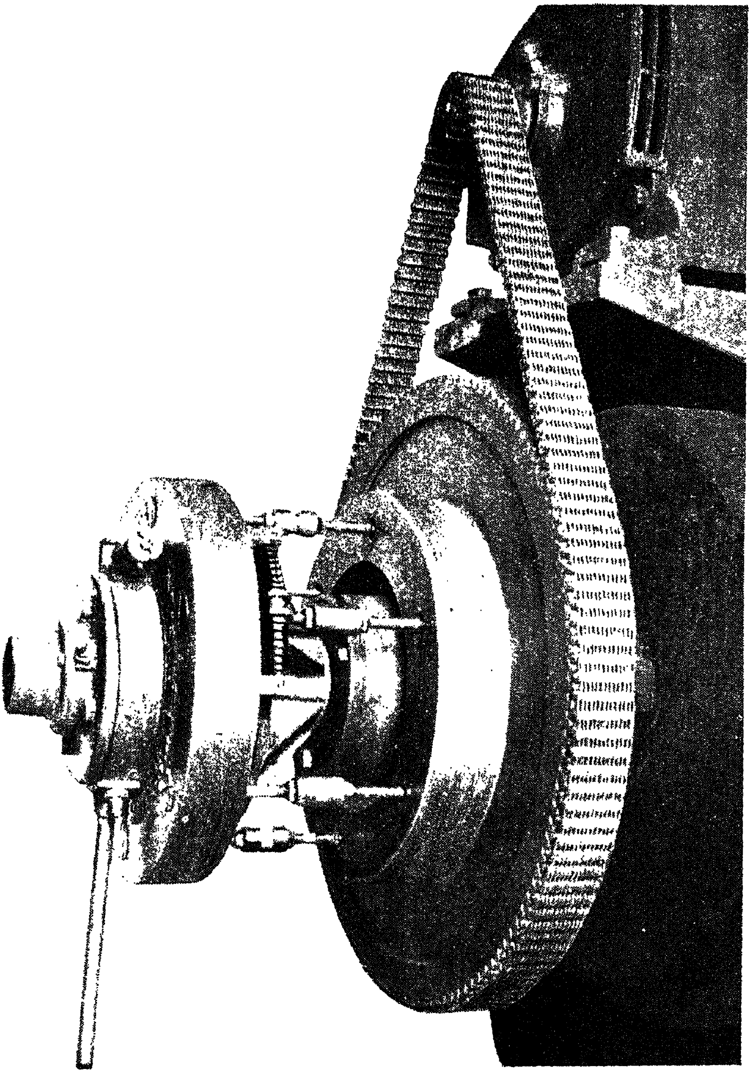


FIG. 172. "LEVELTRIC" CLUTCH AND CHAIN DRIVE
(*Marryat & Scott*)

main motor, depending upon the main motor speed. When the auxiliary motor is started, the clutch operates and connects the main motor shaft to the chain drive, and the lift is then driven up or down by the auxiliary motor at a slow speed. As the speed increases, the main motor is switched on and the motor shaft is then temporarily driven by both motors. When the speed of the main motor increases to a predetermined value, the clutch removes the load from the auxiliary motor, which is then switched off. During the stopping period, the main motor

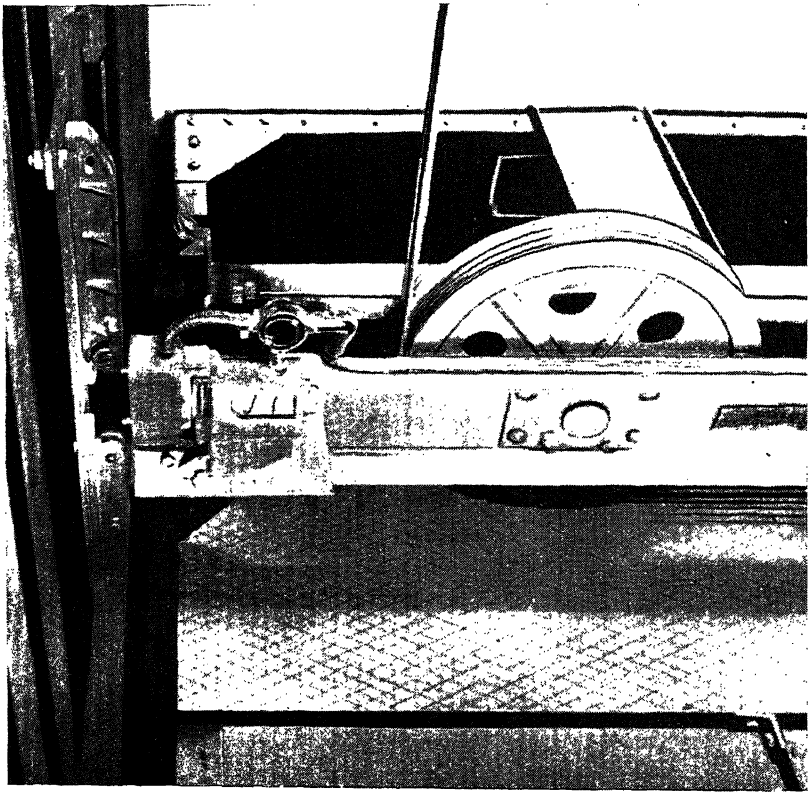


FIG. 173. "LEVELTRIC" LEVELLING SWITCH AND RAMP
(*Marryat & Scott*)

is automatically switched off and the auxiliary motor switched on. The change over from one motor to the other is effected by a levelling switch fitted on the car, this switch engaging

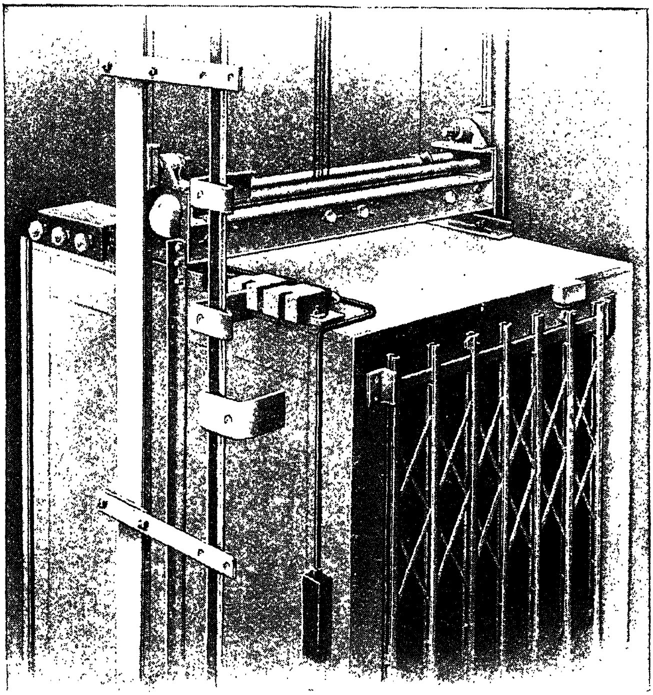


FIG. 174. INDUCTOR SWITCHES MOUNTED ON CAR
(*Express Lift Co. Ltd.*)

with an aluminium ramp at each landing (see Fig. 173). The ramp has a depression in the centre into which the plungers of the levelling switch are guided by rollers on the ramp. The plungers are withdrawn so that they are free from the cams when passing a landing. If the car levels inaccurately, one or other of the plungers will engage with the ramp, thus closing the circuit for the auxiliary motor. This motor then drives the car in the proper direction at slow speed until correctly levelled, when the plungers fall into the cam depression and the switch cuts off the auxiliary motor.

INDUCTOR AND INDUCER SYSTEMS. These patent systems have been developed by the Express Lift Co., and are based upon the fact that the accuracy of levelling depends to a great extent upon an ability to give to the controller an accurate and reliable indication of the position of the car in the well.

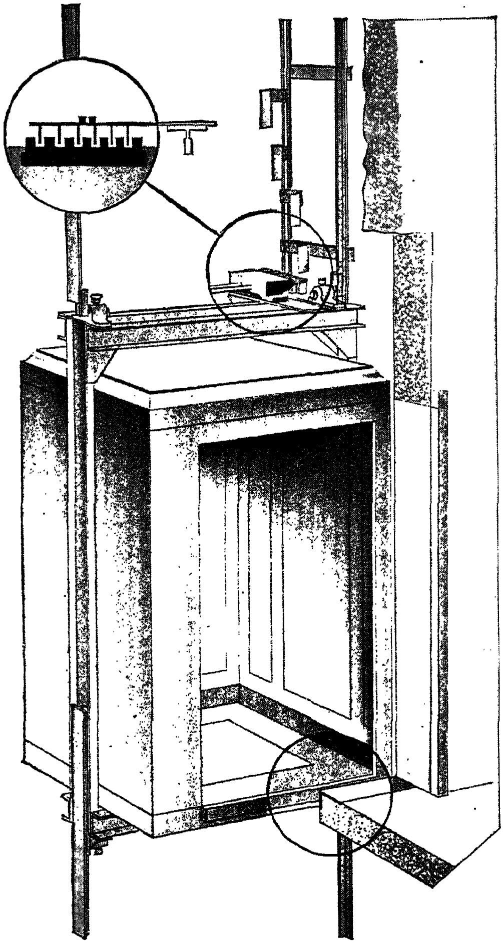


FIG. 175. INDUCER BOX MOUNTED ON CAR
(*Express Lift Co. Ltd.*)

For car speeds up to 300 ft. per min. the Company use inductor or flux diversion relays for signalling the car position to the controller. As many as necessary of these relays are fixed on the lift car, and each is constructed so that a gap exists, through which appropriately fixed iron plates disposed in the lift well may pass (see Fig. 174). On one side of the gap is a magnetic flux generating device, such as a strong permanent magnet; on the other side are flux collecting poles; the flux so collected being used to operate a small armature which itself operates current-carrying contacts. Hence, when an iron plate passes through the gap, the flux is cut off or diverted from the collector so that the armature becomes free to move under the influence of a spring, but as soon as the plate has left the gap, the flux again builds up and the armature returns to its normal position.

It is usual to provide three inductors per car and three associated rows of iron plates fixed in the well; one for counting the zone changes, and one each for controlling up or down slowing and stopping.

For high-speed work, the Company use their inducer system. Essentially this consists of a pair of iron cored coils fixed to the car. A gap between them permits of the entry of an iron plate so that an alternating flux generated by a.c. in one coil may be temporarily prevented from reaching the other pick-up coil. This latter coil is coupled to a valve amplifier so that anode current only flows to operate suitable relays when the plate is in the gap. A number of pairs of coils, depending upon the type of control desired, is fixed to the car (Figs. 175 and 175A), and switching means is provided to couple the appropriate pick-up coil to the amplifier in synchronism with the control stages.

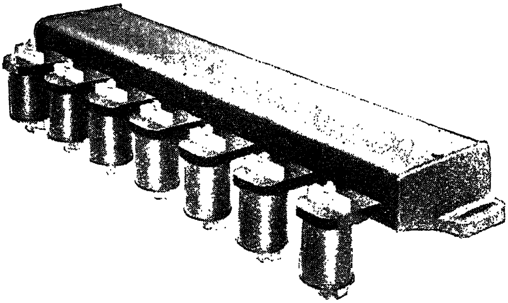


FIG. 175A. INDUCER BOX
(Express Lift Co. Ltd.)

Both of the schemes outlined above operate efficiently to signal to the controller the appropriate moments when to effect the various steps of slowing and stopping, as well as counting the zone changes, without mechanical coupling of any sort being necessary between the car and the well or machine room. Both methods are reliable and silent, and are capable of providing a levelling accuracy of $\pm\frac{1}{8}$ in.

CHAPTER XIV

CAR CONTROL SYSTEMS

A NUMBER of different methods of controlling the movement of the car from floor to floor are available, and the particular one selected depends upon the service required, the type of building, and the car speed. The various methods may be grouped, broadly, into two systems as follows—

(*a*) Those requiring an attendant.

(*b*) Those in which the car is completely under the control of passengers in the car or persons on the landings.

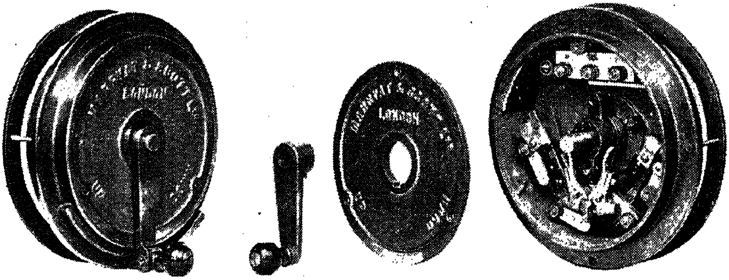


FIG. 176A. SINGLE-SPEED CAR SWITCHES

(*Marryat & Scott*)

In group (*a*) we have systems of control known as *simple car switch*, *pre-register*, *departmental stores*, and *signal*, whilst under (*b*) come *automatic*, *semi-automatic*, and *automatic collective*. *Dual control* may be used with or without an attendant.

Simple Car Switch Control. This control is used for car speeds up to about 400 ft. per min., when the amount of traffic justifies the employment of a lift attendant. A call button is fitted at each landing, and pressure on any button is registered on an indicator board in the car. The attendant is thereby made aware of the floor requiring service. Movement of the car switch to the UP or DOWN START position starts the car; stopping being performed by returning the switch to the Off position as the car approaches the desired floor. Good floor levelling is normally dependent upon the judgment of the operator in returning the switch to the Off position when the car is at the correct distance from the floor. The car switch is of the "dead man" type and, when released, the action of a spring or weight automatically returns it to the Off position. Typical single-speed car switches are illustrated in Figs. 176A and 176B, that at the left in Fig. 176A being of special design, with a gate change hinged knuckle handle. When a multi-speed motor is used, the car switch is provided with additional positions which permit of the final levelling being performed from the slow speed. A two-speed car switch is shown in Fig. 176C.

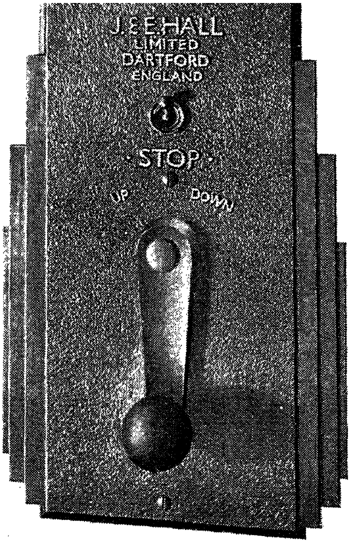


Fig. 176B. Single-speed Car Switch
(J. & E. Hall, Ltd.)

Pre-register Control. A form of control known as *pre-register* control has been developed in America for use on car switch lifts travelling at very high speeds, e.g. 700 ft. per min. and over. With solid type car doors, the attendant cannot see the landings, whilst even with "open" type gates it is difficult to distinguish the floor numbers when travelling at high speeds. In fact, it has been found that at a speed of 800 ft. per min. an operator cannot accurately read floor numbers even when these are painted 4 ft. in height. The main object of this control, therefore, is to supply some signal to the operator which will inform him when to centre the car switch so as to stop at a particular floor. Up and Down buttons are fitted at each intermediate landing, single buttons at the terminal landings, and a button for each floor, together with an emergency stop button in the car. Passengers, on entering the car, call the floors at which they wish to stop, and the attendant presses the appropriate car buttons. The car and landing door contacts are

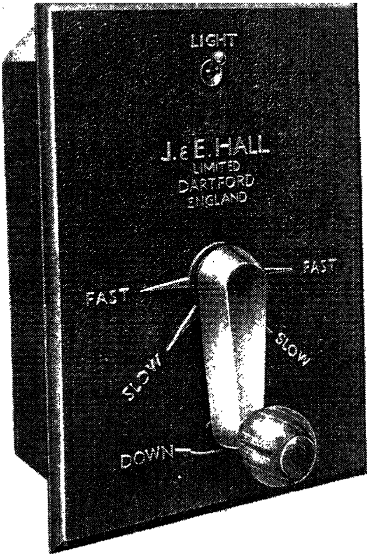


FIG. 176C. TWO-SPEED CAR SWITCH
(*J. & E. Hall, Ltd.*)

electrically connected so that when the switch is moved to the start position the doors automatically close and the car accelerates to full speed. The car buttons are held in the closed positions, thus indicating to the attendant where stops are to be made. When the car enters a stopping zone, established either by pressing a button in the car or a landing button, the appropriate car button flashes a signal light which is an indication to the operator to centre the car switch. The car then slows down and the doors commence to open automatically, when the car is a short distance from the landing; the doors become fully open when the car is correctly levelled. The car buttons are automatically released when the terminal landing is reached. A car switch suitable for this control is shown in Fig. 177.

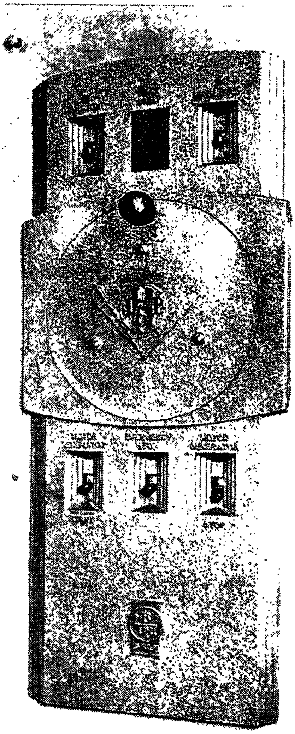


FIG. 177. CAR SWITCH
(*J. & E. Hall, Ltd.*)

Departmental Store Control. This is the name given to a system which has been developed for use in departmental stores where the lift normally stops at each floor and, as with pre-register control, the attendant is relieved of any effort to make accurate landings. Buttons are not required for this control. When the car switch is moved to the START position, the power operated car and landing doors close automatically, and the car commences to accelerate. The centring of the car switch causes the car to stop level with the next floor, and both car and landing doors open automatically. If it is desired to pass floors, the car switch is held in the start position. A car switch for a gearless variable voltage lift incorporating this automatic slowing and stopping feature is shown in Fig. 178.

Signal Control. This is used on banks of high-speed lifts, such as are installed in large offices and hotels, employing

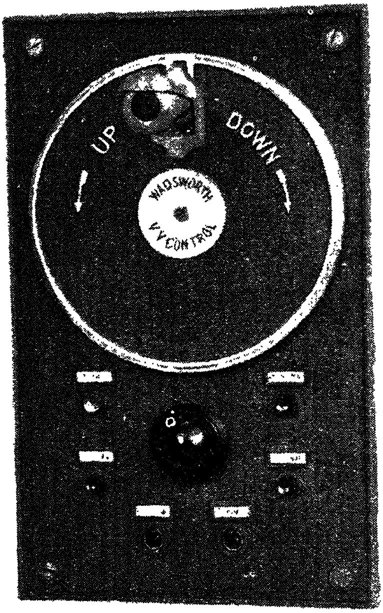


FIG. 178. ESCUTCHEON PLATE FOR CAR SWITCH
Operating handle for variable voltage control
(*Wm. Wadsworth & Sons*)

variable voltage gearless drives, automatic levelling, and power operated doors, and travelling at speeds up to about 600 ft. per min. in this country, and 1 400 ft. per min. in America. The button system is similar to that used for pre-register control. A person at a landing requiring a car, presses either the UP or DOWN button, depending upon the direction in which he wishes to proceed, and the first car travelling in the desired direction and that can accommodate him, stops at the landing. As the car approaches the landing at slow speed (under the control of the automatic levelling gear) the landing light is illuminated, either UP or DOWN, depending upon the direction of travel, thus indicating that the car will stop at that floor. On reaching the landing the car levels automatically, the doors open, and the waiting person enters and calls the number of the floor to which he wishes to proceed. The operator then presses the corresponding car button and moves the car switch to the start position, after which the doors automatically close. The car accelerates and stops automatically at the next floor where a car or landing call has been registered. Car or landing buttons may be pressed in any order, and whether the car is stationary or in motion. A non-stop button in the car enables the attendant to pass any landing if the car is full; the stopping of the first available car resets the control so that unnecessary stops are not made by other cars. A special emergency control lever in the car provides for travel at the slow levelling speed for inspection and maintenance purposes.

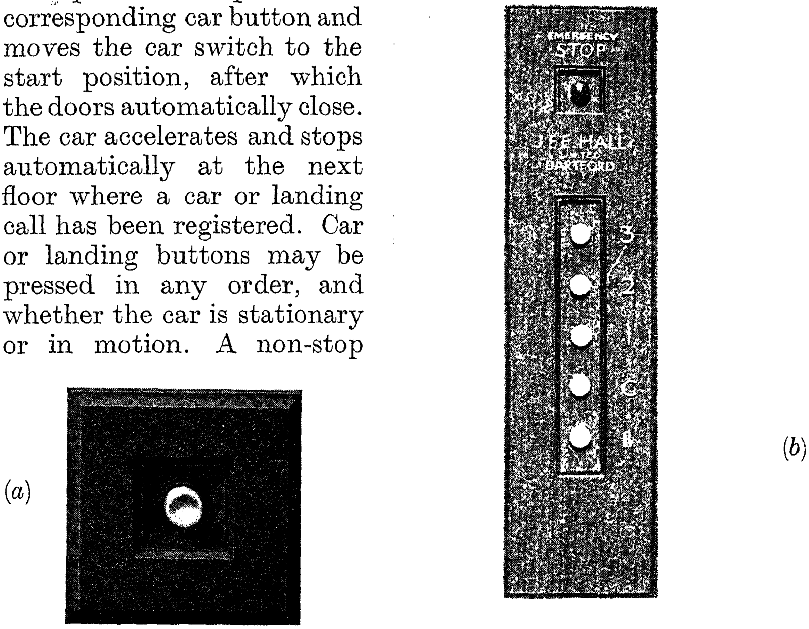


FIG. 179. CALL BUTTONS

(a) Landing call button (b) Car buttons for automatic control

(J. & E. Hall, Ltd.)

Automatic Control. With this type, a single call button is fitted at each landing (Fig. 179 (*a*)) and a set of buttons in the car. The car buttons comprise one for each floor and an emergency stop button, as shown in Fig. 179 (*b*). A passenger, after entering the car and closing the gates, presses the car button corresponding to the desired floor, and the car then starts and automatically stops when the floor is reached. Any other calls which may be made from a landing when the car is in motion are ignored. Whilst the car's ultimate destination is controlled by the passenger, the accuracy of levelling is dependent upon the setting of the slowing and stopping switches and adjustment of the brake, unless automatic levelling gear is installed. This control is used when the traffic is occasional and not sufficiently heavy to justify the employment of an attendant. A button system consisting of a full set of landing buttons (one for each floor) as well as a full set of car buttons, is sometimes employed. This is useful when the lift is used for both passenger and goods traffic and it is desired to send the lift to any floor without a passenger.

Semi-automatic Control. UP, DOWN, and STOP buttons are fitted in the car and at each intermediate landing, whilst UP and STOP buttons are provided at the top terminal landing, and DOWN and STOP buttons at the bottom terminal landing. The momentary pressure of a button, either in the car or on a landing, causes the car to move in the direction indicated, whilst pressure on a stop button stops the car. A modification of this scheme consists of UP and DOWN buttons at each landing and in the car, the car only travelling when the button is actually depressed, and stopping on the release of the button. This results in more accurate floor stopping than with UP, DOWN, and STOP buttons. These systems are sometimes employed in preference to the fully automatic system for slow-speed goods lifts which are not provided with corrective levelling, so as to secure more accurate levelling under varying conditions of load.

The semi-automatic control, however, is now mainly employed on lifts serving two floors only. In this case UP, DOWN, and STOP buttons are fitted only on the landings, when the lift is used solely for goods traffic, but UP, DOWN, and STOP buttons are also required in the car if passengers are to be carried. When two floors only are served, the stop button is for emergency purposes alone, as the lift stops automatically on reaching the floor.

Automatic Collective Control. This system has been developed during recent years with the object of providing a fully automatic push button system giving superior service to that obtainable with the ordinary automatic system. The main disadvantage of the automatic control is that it is possible for passengers waiting at a landing to see the car pass, and travelling in the direction in which they wish to proceed, without them being able to gain admittance. This, however, is not possible when collective control is installed, provided the landing button is pressed sufficiently in advance of the arrival of the car.

UP and DOWN buttons are fitted at each intermediate landing, single buttons at the terminal landings, and a full set of buttons, together with an emergency stop button, in the car. Every button pressed, whether the car is stationary or in motion, registers a call. Up and down calls are answered during the up and down journeys respectively, in the order in which the floors are reached. If the car is at, say, the ground floor and one or more persons enter the car, close the landing and car doors, and press the appropriate car buttons, the car will start, and stop at the floor corresponding to the lowest numbered car button which has been pressed. The order in which the buttons are pressed has no bearing on the sequence in which the car will stop at the various floors, providing that the button for a given floor is pressed sufficiently in advance of the arrival of the car at that floor to enable the stop to be made. The car, while travelling in the up direction, will also stop in the same manner in response to all up landing button calls. The upward direction is continued until the uppermost call has been answered. If a down call is registered at a floor above the highest up stop, the car will continue in the up direction to the floor at which a down call is registered. It will then reverse automatically, even though not at the top terminal floor, provided car buttons for floors above this point have not been pressed, and will start down, stopping in response to all down calls registered at lower floors in advance of the arrival of the car at these floors. The car will continue in the down direction until the last floor is reached for which a car or down landing button has been pressed. If, after all down calls are answered, the car is not at the bottom landing, it will continue down in response to the pressing of an up button at a floor below the last stop. If, however, no button is pressed below this floor the car will reverse automatically, and start up in response to the pressing of either up or down buttons above this floor. In other words, the car will travel in either direction until the last floor has been reached at which an up or down button has been pressed, or for which a car button has been pressed. It is not necessary that the car make complete round trips.

If traffic is intermittent and only one call is registered at any one time, the lift will operate in the same manner as a single automatic push button lift, but will become collective automatically when more than one call is registered at one time.

Precedence is given to the passenger in the car in the following manner. If, after the car has started to slow down at a given floor in response to the pressing of a button at that floor (this call being the last call registered in the direction in which the car is going) another call is registered at a floor beyond the one at which the car is in process of stopping, the stop will be completed. After the passenger has entered the car he may dispatch the car in accordance with his wishes, provided he presses the proper car button before closing the car gate or within about five seconds after the car gate has closed. He is, therefore, spared the inconvenience of being taken in the direction opposite to that which he expected to go. For example, if the car is at the first floor and down buttons are pressed at the third, fifth, and seventh floors, the car will travel to the seventh floor. If, after the car has commenced to stop at the seventh floor, an up or down button is pressed at the ninth floor, the stop at the seventh floor will be completed and the call at the ninth floor will not be answered until after the car has reversed at the seventh floor and completed its downward trip in response to the car buttons pressed by the passengers who entered the car at the seventh, fifth, and third floors. If the ninth floor button had been pressed before the car commenced to stop at the seventh floor, the car would have proceeded to the ninth floor before answering the down calls at the lower floors. The same operation is effective in both directions. If, after the car has stopped at a given floor in response to the pressing of either a car or landing button, the car or landing door is not opened within about five seconds, the car will respond to any other calls which may be registered, or if no calls are registered, the car will return to the home landing.

Arrangements may be made to enable the car to park automatically at any preselected floor, after all calls have been answered, this facility being particularly desirable when important persons are located on a certain floor or when heavy traffic is expected from a particular floor at certain periods of the day. For instance, the service may be greatly improved in a block of offices if, during heavy morning traffic, the car is made to return automatically to the ground floor or to park at, say, the sixth floor in the evening, to give prompt service in the downward direction instead of remaining at the floor to which it was last called.

The above form of control, which is sometimes referred to as *directional collective*, may be modified to enable calls to be answered in the same sequence in which the buttons are pressed. This is known as *interceptive collective* control.

The system may be still further modified to work as an automatic push button control in the up direction and as directional collective in the down direction only. This down collective control is sometimes employed in flats and is based on the assumption that, whilst tenants and their visitors travelling upwards usually wish to travel directly to their own floor, all persons travelling downwards wish to alight at the ground floor. Hence, an upward travelling passenger is enabled to travel directly to his own floor without interference, whilst in the downward direction there is no reasonable objection to the lift stopping at intermediate floors to pick up other passengers who almost certainly also wish to travel downwards to the ground floor.

Dual Control. This is a combination of car switch control and either automatic or automatic collective control. A car switch and a set of buttons for automatic working are required. The lift may be worked either by car switch with an attendant, or by push buttons, depending upon the position of a control switch in the car. For ordinary traffic the lift is operated automatically, and during periods of peak loads as a car switch lift, with a consequent improvement in the service.

Automatic Dispatching of Cars. Although signal control is a most efficient system for dealing with the traffic carried by a bank of high-speed lifts, it is possible that the service given may be poor if the lifts are not used efficiently. It is quite conceivable that at any given instant several cars may be in the vicinity of the same landing, and, consequently, the service given to other landings will suffer. The service can be greatly improved if this possibility is eliminated by employing some means whereby, at any instant, the positions of the cars in the wells are such that they are approximately equally spaced from each other. To achieve this object automatic dispatching of the cars from the ground floor at regular intervals has been adopted on many of the large American lift installations. Each car in the bank is fitted with green, red, and white lights; the green being the operator's signal to leave the ground floor; the red, the signal to start from the top floor, whilst the white indicates to the attendant when he should be at the half-way position in the well for his schedule to be maintained. For example, with a bank of six cars, the round trip time of each being 180 sec., the green light will flash in car No. 1 when it is time for commencing; 30 sec. later No. 2 green light will flash and the remaining four lifts will be dispatched at intervals of 30 sec. The white lights will flash in the cars 45 sec. and 135 sec. after their commencements, i.e. at the half-way positions on the up and down journeys respectively. Each car receives a signal on its red light 90 sec. after the start from the ground floor. The scheduling machine consists of three motor-driven arms which operate the car lights, and duplicate green, red, and white lights in the dispatching cabinet on the ground floor. If the arms on the machine are uniformly spaced, the cars will be dispatched at equal intervals as described above, but during rush periods, when the traffic is out of balance, the arms may be adjusted so that the red and white lights allow longer running times in one direction. For instance, in the case quoted, 100 sec. may be allowed on the upward journey during the morning, and 80 sec. on the down journey, and vice versa at night. The arms may be further adjusted, if necessary, to speed up or slow down the normal schedule. A car position indicator and tell-tale annunciator are fitted at the dispatching position, the former showing the position of each car in the well and the latter the floor calls. Hence if the dispatcher observes that a particular car is having an unusual number of calls, some of these can be passed and left for the following car to answer.

CHAPTER XV

CONTROLLERS

General. The controller is usually located in the motor room, but care should be exercised in choosing its exact position in order to ensure that sufficient clearance exists between the controller and any walls, and, further, that there is no possibility of a maintenance engineer, when working on the controller, coming into contact with a moving part of the lift. The various contactors, relays, auxiliary resistances and fuses are mounted on a panel of slate, "Sindanyo," or other insulating material, the panel in turn being fixed to an angle iron framework. (A group of three controllers for a.c. commutator motors

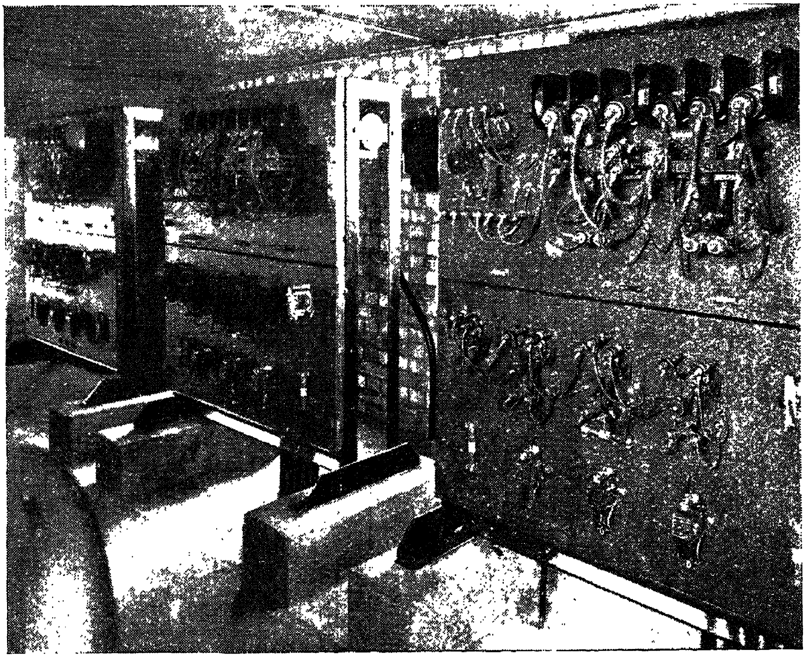


FIG. 180. THREE CONTROLLERS FOR A.C. COMMUTATOR MOTORS
(Motors: B.T.-H.; Lifts: Waygood Otis)

is shown in Fig. 180, these being the controllers for the lifts shown in Fig. 54.) The control relays and the starting, accelerating, and retarding contactors, together with their associated interlocks, are electromagnetically operated, the magnet coils being supplied from the control voltage. Contacts performing certain operations require delayed actions of varying durations, and this is effected usually by dashpots, or preferably mechanical time lags. Copper-to-carbon and copper-to-copper are the contact combinations generally adopted; the modern trend being towards the copper-to-copper contacts. Blow-out coils are fitted where necessary to the contactors in order to extinguish the arc, and when copper-to-copper contacts are used these must be carefully designed to give a "rolling" contact. By this means the portions of the contact surfaces on which the circuit is made and broken, and which suffer any deterioration due to arcing, are slightly removed from the portions which actually carry the current. If the contacts are not correctly designed and the roll is insufficient, or is lost due to faulty maintenance, there is danger that the arcing will cause

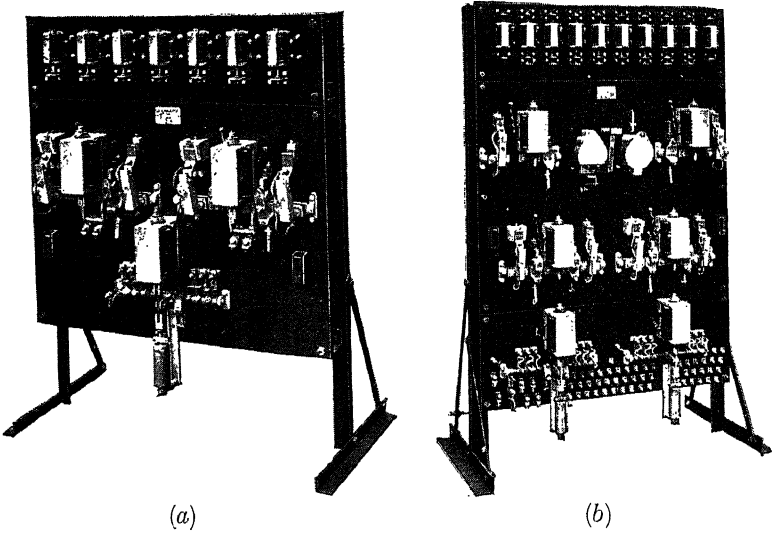
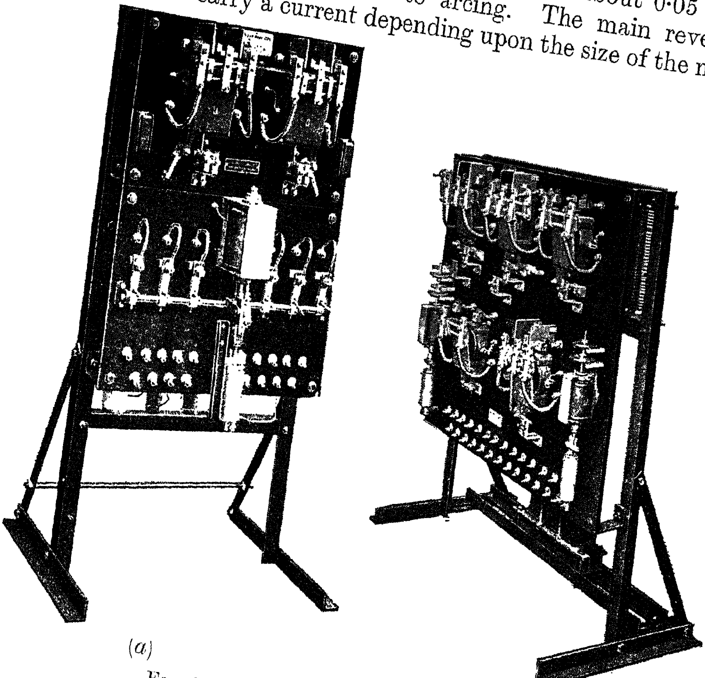

(a) (b)

FIG. 181. AUTOMATIC CONTROLLERS FOR D.C. MOTORS

(a) Single-speed controller (b) Two-speed controller

(J. & E. Hall, Ltd.)

the contacts to weld, and if the reversing contactors are so affected serious damage may result. Copper contacts are sometimes faced with silver of a thickness up to about 0·05 in. to minimize deterioration due to arcing. The main reversing contactors carry a current depending upon the size of the motor and at the voltage of the motor supply, whilst the operating coils of the contactors, relays, and brake carry comparatively small currents, the voltage being either that of the mains (a.c. or d.c.) or a separately produced control voltage. (Fig. 181 (*a*) and (*b*) show two automatic controllers for d.c. motors, the former being single-speed and the latter two-speed with shunt regulation and diverter control.) D.c. magnets are more silent and generally more reliable than a.c. magnets and it is, therefore, frequently the practice to supply all control circuits and



(*a*) (*b*)

FIG. 182. CONTROLLERS FOR A.C. MOTORS

(*a*) Single-speed controller. (*b*) Controller for two-speed squirrel-cage motor

(*J. & E. Hall, Ltd.*)

the brake coil from a direct voltage which, in the case of a.c. mains, is obtained from a double-wave rectifier. The control voltage employed is generally between 100 and 200 volts except when dual voltage control is used. Fig. 182 (*a*) and (*b*) shows two controllers for a.c. motors with rectified d.c. control.

Dual Voltage Control System. In the control system used by the Express Lift Co. and known as their *dual voltage control system*, the motor is operated direct from the mains, whilst the control circuits are worked from 50 volts d.c., the latter voltage being obtained from static rectifiers. The system is capable of providing any desired form of lift control, and is reliable, quiet in operation, and occupies the minimum space in the control room. The fact that all control is effected by direct current at a pressure of only 50 volts means that fire risk is greatly reduced, wiring is simplified, and electrical wear, which is mainly due to arcing at contacts, is negligible.

The development of the system has been made possible, firstly, by the use of the now so popular static copper oxide rectifier and, secondly, by the use of principles and apparatus commonly used in automatic telephone exchanges. All of the telephone type equipment used is similar to that used by the British Post Office and is the result of intensive research and development during the last thirty years by firms such as the General Electric Co., who have acted as advisors and consultants to the Express Lift Co.

Each controller is a self-contained unit consisting of a light but strong steel frame cabinet, within which are mounted several distinct groups of apparatus. Fig. 183 shows a dual voltage controller for slip-ring variable voltage control. Immediately below the sheet steel lid is a shelf upon which are mounted all terminals for the external circuits. Below this terminal shelf are five horizontal sections. In the top one are mounted the accelerating tuning resistances and the decelerating brake tuning resistance; here also is space for a phase-reversal relay and other similar extra apparatus. In the second section all of the automatic control equipment is mounted in groups in sealed steel boxes; this apparatus is all of the telephone type, and each box is provided with special connecting plugs so that any group may be easily removed and a new one plugged in. It is by this means that the various forms of lift

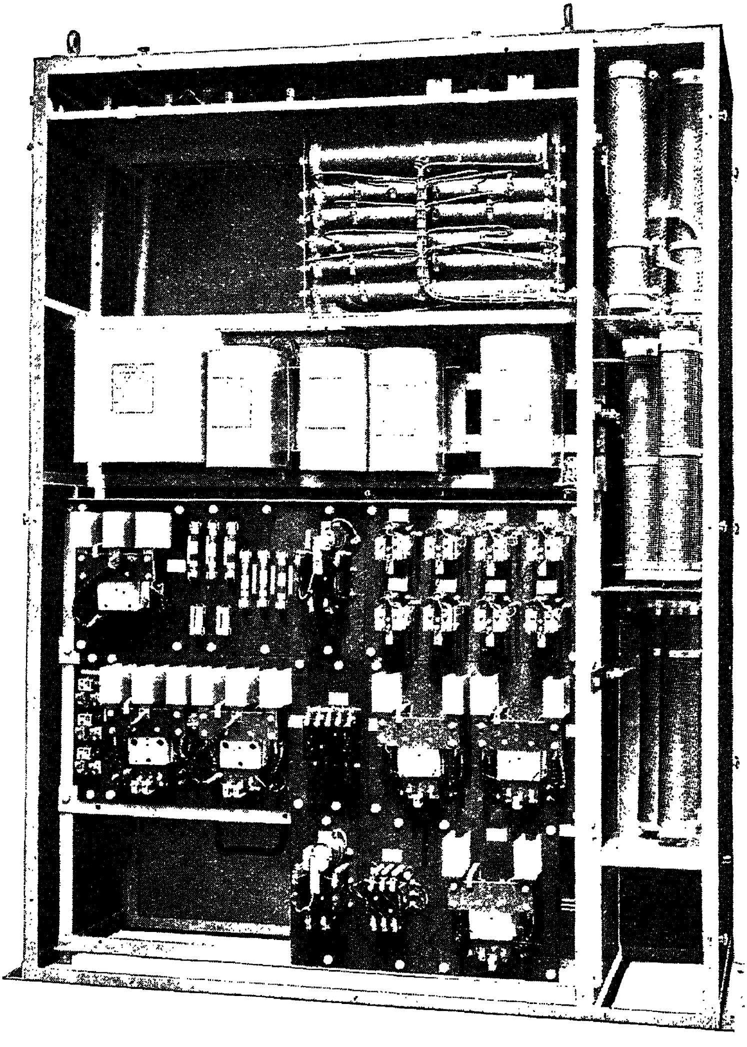


FIG. 183. DUAL VOLTAGE CONTROLLER FOR SLIP-RING VARIABLE VOLTAGE CONTROL

(Cover removed)

(*Express Lift Co. Ltd.*)

control can be readily provided, besides improving the servicing facilities. Behind this section is a shelf carrying various pieces af apparatus, and especially acting as a support for some of the rectifiers. The third section contains vertical panels carrying the main circuit-breaker, fuses, and decelerating controlling contactors. The fourth section contains the mechanically and electrically interlocked reversing contactors, the overload trips, and accelerating contactors. The last section carries further auxiliary contactors and relays. Down the right-hand side of the framework space is reserved in which the motor rotor resistances are mounted.

The main line voltage appears only at the motor controlling contactors, fuses and overload trips, and at the input terminals of the rectifier systems, of which there are three. The main one of these is fed via a transformer and gives an output of 50 volts, full wave rectified, to supply the energy for all of the operating coils of relays, contactors, and selector switches; hence the control system is in effect isolated from the mains. It will be apparent that the main reason for adopting 50 volts for the control section of the equipment is in order to be able to use the telephone type apparatus which is invariably designed to work at that voltage. The other two rectifier systems both give direct current outputs at a pressure of the order of 170 volts; one supplies energy to the eddy-current brake during the slowing period and the other supplies energy to the friction brake, to hold it off during the running period.

An indication has already been given in Chapter V of the method of controlling the acceleration, running, and deceleration of the motor with slip-ring variable voltage control, and in Chapter XIII of the method of keeping the control circuits *au fait* with the movements of the car. It therefore only remains to outline how the actual control is effected.

An electromagnetic rotary selector switch indirectly responds to signals received from an inductor relay on the car in order to keep in synchronism with the car movements, and so record which zone the car is in. Co-operating with this switch is a group of relays which, by their action and ability to self-hold, record incoming calls both from landings and from the car. The result of this co-operation is a decision as to the direction in which the car shall travel, and the floor at which it shall be stopped. A further group of relays determines the manner in which the car shall respond to calls; in fact, whether the lift acts as a simple fully automatic push-button installation or something much more complicated.

Low voltage control has proved so successful that it is now applied by the Express Lift Co. to all lift systems designed to work with an a.c. mains supply.

Control Features. One of the most important functions of a controller is to ensure that it is impossible for the lift to be operated when any landing or car gate is open. This is usually effected by wiring the gate interlocks in series in one of the mains to the control circuits (see Chapter X).

With automatic lifts it should not be possible to interfere with the car's motion by operating a landing button when a passenger has entered or is travelling in the car. A delayed contact associated with the car gate contact is arranged to cut out the landing buttons for about five seconds after the passenger has entered the car and closed the gates. He is thus allowed this period in which to select and operate the required car button (see Chapter X). If the car button is not pressed during this interval, the car may be called to any floor by the operation of the relative landing button. Immediately a car button is pressed, however, the controller is arranged to cut out the landing buttons until the car has reached the end of its journey and the passenger has left the car and closed the gates. This is effected by incorporating a relay which is energized by the pressing of a car button, the relay contacts cutting out and re-inserting the landing buttons at the commencement and end of each journey respectively.

To guard against the possibility of the car or counterweight encountering an obstruction, a relay is connected in the mains and is energized when a reversing contactor operates. After a period of from 1½ to 2 complete journeys, a lagged contact (one with delayed operation) of this relay is arranged to cut off the control supply. This contact is usually of the hand reset type, and therefore the cause of the trouble may be removed before resetting the contact. As a precaution against the main contactors welding it is sometimes the practice to arrange that this delayed contact disconnects the no-volt coil on the main circuit-breaker, and thereby cuts off both the motor and control circuits. Another method of providing this safeguard is by arranging that a condenser discharges through a neon tube if the controller remains energized longer than required. The discharge current operates a relay which cuts off the control supply.

A reverse-phase relay should be incorporated in the controller of a polyphase motor; the functions of this relay being to guard against damage to the motor due to low voltage, phase reversal, and phase failure. The relay operates on the induction motor principle, a disc acting as the rotor. The relay contact is opened and closed by the motion of the disc and is kept closed by the operating coils when the phases are in proper relation. When reversal occurs, the rotor turns in the opposite direction thereby opening the relay contacts which in turn cut off the motor supply and prevent operation of the motor in the wrong direction. Low voltage reduces the relay torque and the contacts again open, thus cutting off the motor supply and preventing possible stalling, burn-out, and increased speed. When phase reversal occurs, the relay loses its torque and the contacts open and thus guard against a possible motor burn-out due to running on single phase.

It is frequently the practice to interlock the motor and control circuits so that, in the event of a failure of the motor supply, the control supply is automatically disconnected. This is achieved with a polyphase motor supply and a single-phase control supply by inserting two relays in the mains, these relays being supplied from different pairs of line wires. A contact of each relay is joined in series in the control supply so that in the event of any phase becoming disconnected the controller is cut off. With a rectifier d.c. control supply the two circuits may be interlocked by means of two opposed relay coils; one supplied from the d.c. control voltage, the other from a separately rectified d.c. voltage obtained from the polyphase motor supply. When both coils of the relay are energized, the contact closes and completes the control circuit. If either the motor supply or the control supply fails, one of the coils is disconnected and the relay contact thereby opened.

To safeguard the motor against possible damage caused by the operation of the reversing contactor before the motor has come to rest, a lagged contact is wired in the control supply to the reversing contactor coils. This contact closes a few seconds after the reversing contactor opens at the end of a journey, thus giving the motor time to come to rest before the contactor can be re-energized.

In addition to the reversing contactors being electrically interlocked, i.e. an auxiliary contact of each contactor being joined in series with the operating coil of the other, they are sometimes mechanically interlocked as an additional safeguard against both operating together.

Other electrical interlocks have for their objects the prevention of the fast- and slow-speed contactors operating together, and ensuring that any accelerating and decelerating rheostats are inserted in correct sequence. The control circuit is sometimes interlocked with the brake hand release so that the controller is disconnected when the brake release is operated. It is thus impossible for the lift to be operated if the hand release has been overlooked after operation during testing. When the car safety gear operates, the motor is overloaded, and to prevent the possibility of damage if the fuses fail to blow, an interlock switch is frequently fitted to the gear so that when the safety gear sets, the switch cuts off the control circuit. In addition, this switch prevents the car moving if the proper clearance does not exist and the safety jaws scrape the guides.

A further facility invariably provided on lift controllers consists of a change-over switch, the operation of which, together with the pressing of associated test buttons, permits of the lift being worked from the motor room for test purposes.

It is now recognized that accurate lift working records are an essential to efficient maintenance and service, and therefore energy meters to record the lift's electrical consumption, and counters to record the number of operations of the controller, are now being fitted as standard items of the control equipment. Operation counters are usually of the "Veeder" pattern and generally register the number of operations of the reversing or accelerating contactor. More complete data are obtained by fitting, in addition to an operation counter, a revolution counter on the main driving shaft and thus obtaining a record of the distance travelled by the car during any period.

CAR SWITCH CONTROLLERS

With this type of controller, floor selection and stopping are usually controlled entirely by the movement of the car switch, although with many modern high-speed controllers the stopping is performed automatically and independently of the car switch. In the latter types the car switch only performs the functions of starting and of selecting the floors at which stops are to be made, the switch being returned to the Off position after passing the floor immediately preceding that at which a stop is required. With ordinary single- or two-speed controllers for speeds up to about 150 ft. per min. and 350 ft. per min. respectively, starting and accelerating are performed by moving the car switch in the appropriate direction to the first position. If two speeds are employed, the switch is then moved to the second position, after which the motor accelerates to its full speed. On approaching the desired floor, the switch is returned to the first position and the motor decelerates to its lower speed. Finally, the switch is returned to the Off position and the car is brought to rest, the accuracy of the levelling depending upon the operator's judgment in returning the car switch at the correct moment.

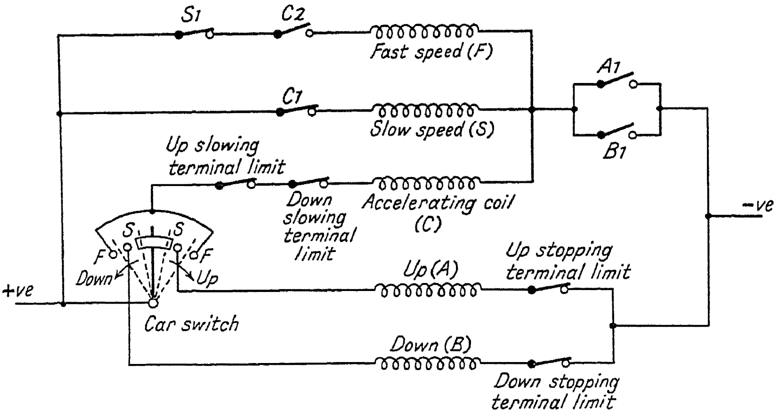
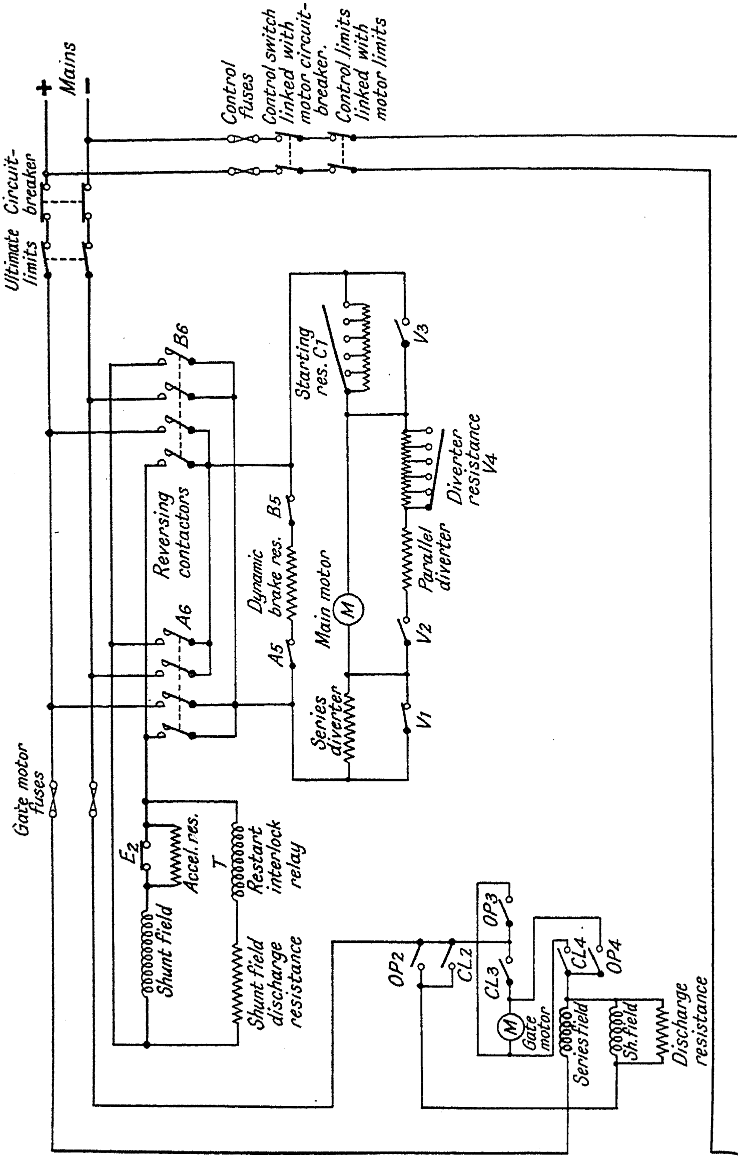

S1
C2
Fast speed (F)
A1
C1
Slow speed (S)
B1
Up slowing terminal limit
Down slowing terminal limit
Accelerating coil (C)
−ve
S
S
F
F
Down
Up
+ve
Car switch
Up (A)
Up stopping terminal limit
Down (B)
Down stopping terminal limit

Fig. 184. Elementary Two-speed Car Switch Control Diagram

Elementary Car Switch Controller. The fundamental operations of a two-speed controller will be understood by referring to the diagram shown in Fig. 184. In this, as in subsequent controller diagrams, the detached contact method of drawing the diagrams has been adopted, in which the contacts of an electromagnet bear the same letter as that given to the magnet operating coil; thus *C*1 and *C*2 are contacts of an electromagnet whose operating coil is labelled *C*. All contacts are shown in their normal positions, i.e. with the lift at rest. From the diagram it will be seen that there are five positions for the car switch, a slow position and a fast position for each direction of travel, and a centre off position. When the car switch is moved to the up direction, first position, a circuit is made for coil *A* of the main UP contactor via +ve main, car switch, *A*, UP stopping terminal limit, and –ve main. The reversing contactor (not shown), operated by *A*, closes and connects the supply so that the motor is ready for operation in the UP direction. Contact *A*1 closes and a circuit for the slow-speed coil *S* is made via +ve, *C*1, *S*, *A*1, and –ve. The contactor operated by *S* (not shown) now closes and joins the main supply through to the slow-speed winding of the motor from the reversing contactor of *A*. Interlock *S*1 opens and thus prevents the possibility of the fast-speed winding being energized at the same time as the slow-speed winding. The motor now accelerates to its first speed, after which the car switch is moved to the fast-speed position. A circuit for the accelerating coil *C* is now completed via +ve, car switch, two slowing terminal limit switches, *C*, *A*1 to –ve. The car switch contact arm bridges the slow- and fast-speed positions so that, when in the latter position, the coil *A* remains energized. The opening of *C*1 and the closing of *C*2 disconnects coil *S* and provides a circuit for coil *F* respectively, the circuit for *F* being via +ve, *S*1, *C*2, *F*, *A*1, and –ve. The contactor of coil *F* (not shown) operates and connects the mains to the motor high-speed winding immediately the low-speed winding has been disconnected. The motor now runs at its maximum speed.

On approaching the desired floor, the car switch is returned to the slow-speed position, thus disconnecting coil *C* which in turn disconnects *F* by the opening of *C*2 and completes a circuit for *S* when *C*1 closes. Stopping is thus performed from the slow speed. When the car has run sufficiently near to the floor at slow speed the car switch is centred, thus disconnecting


Mains
+
−
Circuit-breaker
Ultimate limits
Control fuses
Control switch linked with motor circuit-breaker.
Control limits linked with motor limits
B6
Starting res. C1
V3
Reversing contactors
Dynamic brake res.
B5
A5
A6
Main motor
M
Diverter resistance V4
Parallel diverter
V2
Series diverter
V1
Gate motor fuses
E_2
Accel. res.
T
Restart interlock relay
Shunt field
Shunt field discharge resistance
OP2
CL2
OP3
CL3
CL4
OP4
M
Gate motor
Series field
Sh. field
Discharge resistance

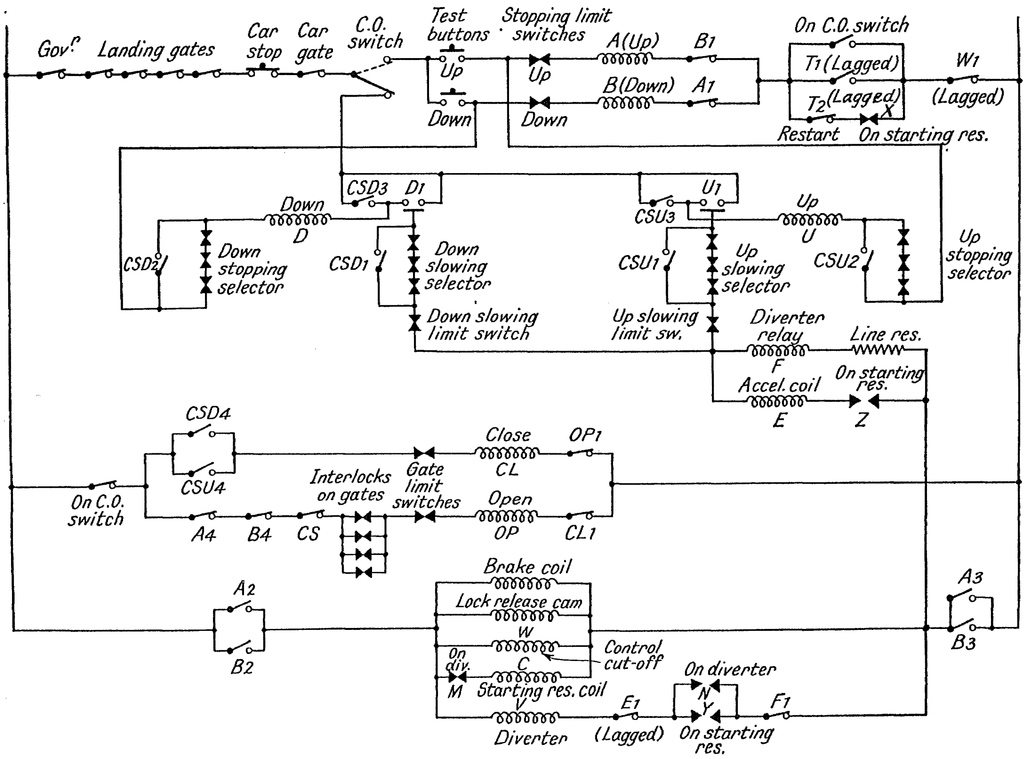


FIG. 185. FOUR FLOOR CAR SWITCH CONTROLLER WITH TWO-SPEED D.C. MOTOR STRAIGHT-TO-FLOOR LEVELLING AND POWER-OPERATED GATES

CS Car switch contacts: operate on both UP and DOWN directions
CSU Car switch contacts: operate on UP direction only
CSD Car switch contacts: operate on DOWN direction only
⧓ Contacts operated mechanically and automatically

coil *A* and cutting off the supply from the motor. The brake then automatically operates and stops the car.

Running in the down direction is performed in a similar manner except that the Down coil *B* is energized instead of *A*.

The terminal limit switches shown, automatically bring the car to rest at either terminal landing if the operator does not centre the car switch. Two switches—one slowing and the other stopping—are fitted near the bottom landing and two similarly near the top landing. These switches are operated by the movement of the car and may be fitted in the well, in which case they are operated by a cam on the car, or they may be situated in the motor room and operated by a camshaft driven from the car by a flyrope. The slowing switch operates a little in advance of the stopping switch so that the lower speed is reached before the stopping switch is operated.

Four-floor Car Switch Controller with Two-speed D.C. Motor, Straight-to-floor Levelling, and Power-operated Gates. The wiring diagram for a controller of this type, manufactured by Messrs. Wm. Wadsworth & Sons, is shown in Fig. 185, but it should be borne in mind that controllers vary considerably, the actual details depending upon the customer's requirements. The diagram illustrated can readily be modified to include almost any operating feature desired.

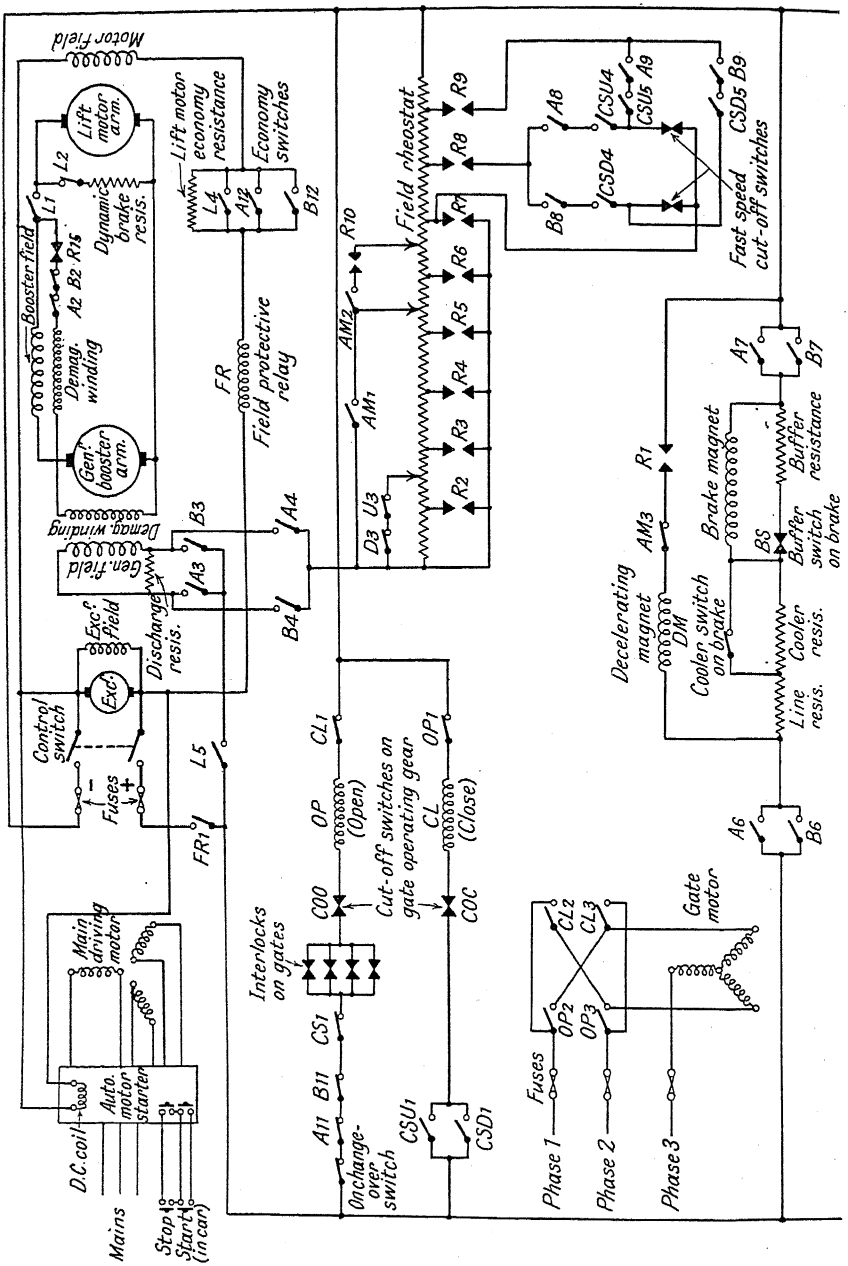
Assume that the car is at the fourth floor and that it is being brought down to the first floor. The moving of the car switch to the Down position completes a circuit for the door closing relay *CL* via +ve, interlock on change-over switch, *CSD*4, gate limit switch, *CL*, interlock *OP*1 to –ve. Interlock *CL*1 opens and guards against the possibility of *OP* being operated. *CL*4 closes and connects the +ve line through the series field to the armature of the gate motor, whilst *CL*3 connects the –ve to the armature and *CL*2 joins the –ve line to the shunt field. The gate motor then closes the gates, the motor circuit being cut off when the gate limit switch opens and cuts off *CL*.

The circuit for the down contactor coil *B* is completed via governor switch, landing gate contacts, car stop button, car gate interlock, change-over switch, *CSD*3, coil *D*, *CSD*2, Down stopping limit switch, coil *B*, *A*1, *T*2, *X*, and *W*1. The Down contactor *B*6 closes and connects the motor to line. *B*1 opens and guards against the operation of *A*. *B*2 and *B*3 close and energize the brake coil, lock release cam, *W*, and the starting resistance coil *C*. The starting resistance *C*1 is gradually cut out and the motor speed increases to the first speed. *Z* then closes and the accelerating coil *E* is energized via *D*1, *CSD*1, down slowing limit switch, *E*, *Z*, and *B*3. The accelerating resistance in the shunt field is now inserted by the opening of *E*2 and the motor speed rises to its full value.

When approaching the first floor, the car switch is returned to the centre position and all *CSD* contacts open. The slowing down selector for the first floor opens and cuts off the accelerating coil *E*, thus cutting out the shunt field resistance by the closing of *E*2 and causing the motor speed to fall to its slow speed. Contact *E*1 falls back a few seconds later and energizes coil *V* via *B*2, *V*, *E*1, *Y*, *F*1, and *B*3. Contact *V*2 closes and the diverter resistance *V*4 is gradually inserted across the armature. *V*1 opens and inserts the series diverter, whilst *V*3 short-circuits the starting resistance *C*1. *M* opens and cuts off coil *C*, thus causing *Y* to open. A holding circuit for coil *V* is provided by the closing of contact *N*. The motor speed now falls to the slow levelling speed.

The down stopping selector for the first floor next opens and cuts off the supply from the reversing coil *B* and contactor *B*6 opens. Contact *B*5 closes and inserts the dynamic brake resistance, whilst the opening of *B*2 and *B*3 applies the mechanical brake and disconnects the remaining controller coils.

When the car switch was returned to its centre position, *CS* closed and prepared the circuit for coil *OP* of the gate opening relay. The closing of contacts *OP*2, *OP*3, and *OP*4 completes the circuit for the gate motor and the gates open when the car arrives at the landing and the interlock switch on the gate lock closes. The interlock switches are attached to the gate lock interlock levers, these being actuated by the lock release cam which is withdrawn during the running period and is only released when the brake coil switches open and the brake operates. The Up and Down slowing limit switches automatically slow down the car to its slow speed at the terminal landings, whilst the up and down stopping switches automatically stop the car at the terminal landings if the car switch has not been centred. Contact *W*1 is lagged for a period of about


Motor field
Lift motor arm.
L2
L1
Booster field
A2 B2 R15
Dynamic brake resis.
Lift motor economy resistance
Economy switches
L4
A12
B12
Demag. winding
Gen.r booster arm.
Demag. winding
Gen. field
FR
Field protective relay
Field rheostat
R10
R9
R8
R7
R6
R5
R4
R3
R2
AM2
AM1
U3
D3
A8
CSU4
CSU5 A9
CSD4
B8
CSD5 B9
Fast speed cut-off switches
A7
B7
Brake magnet
Buffer resistance
R1
AM3
BS
Buffer switch on brake
Decelerating magnet DM
Cooler switch on brake
Cooler resis.
Line resis.
A6
B6
B3
A4
A3
B4
Exc.r field
Exc.
Discharge resis.
Control switch
Fuses
L5
FR1
CL1
OP1
OP (Open)
CL (Close)
Cut-off switches on gate operating gear
COO
COC
Interlocks on gates
CS1
B11
A11
On change-over switch
CSU1
CSD1
Main driving motor
D.C. coil
Auto. motor starter
Mains
Stop
Start (in car)
Gate motor
CL2
CL3
OP2
OP3
Fuses
Phase 1
Phase 2
Phase 3

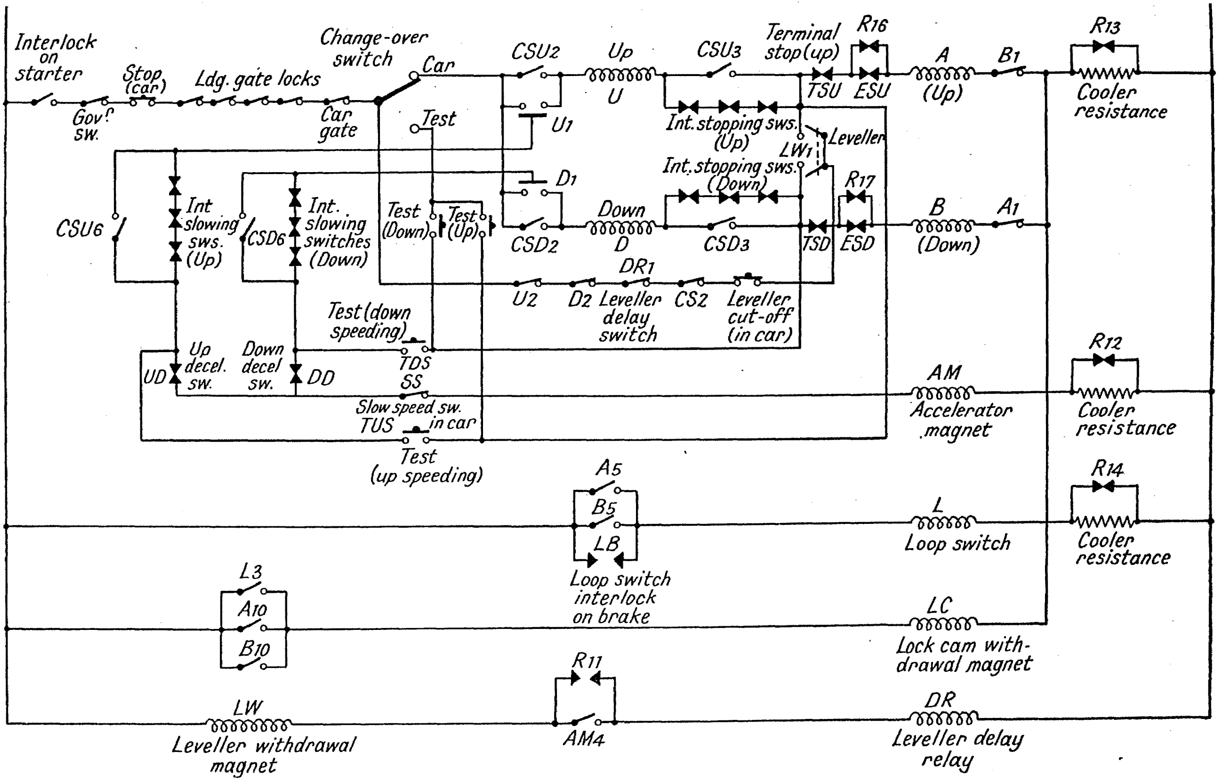


FIG. 186. CAR SWITCH VARIABLE VOLTAGE GEARLESS MOTOR CONTROLLER

Four floors

1½ complete journeys, and when operated cuts off the control circuit. Contact *T*2 prevents the motor being restarted before it has stopped rotating, whilst contact *X* prevents starting with the starting resistance cut out.

Four-floor Car Switch Controller with Gearless Motor, Variable Voltage Control, Straight-to-floor Levelling, and Power-operated Gates. Fig. 186 is a diagram of Messrs. Wm. Wadsworth & Sons' controller of this type. A brief description of the equipment, which is shown in Fig. 65, will, no doubt, assist in following the operations of the control circuits.

The motor generator set runs constantly the whole time the lift is in service, whilst the direct coupled exciter provides the direct current necessary for energizing the brake coils, control gear magnets, and the field coils of the generator and the slow-speed lift motor. The generator armature is coupled, with one intermediate switch to the lift motor armature so that the only current handled by the lift controller is that of the generator field, brake and control circuits. The driving motor of the set is an ordinary squirrel-cage induction motor with a synchronous speed of 1 500 r.p.m. for the smaller sets, and 1 000 r.p.m. for the larger ones. Starting of the motor generator set is accomplished by one or more of the following methods—

(1) Start and stop buttons in the car.

(2) Starting when the car switch is moved to the starting position. Automatic stopping is adjustable up to ten minutes after the lift was last used.

(3) Starting when the lift operating push (car or landings) is pressed momentarily and stopping performed automatically as in (2).

The generator incorporates in itself a series connected booster, the function of which is to increase or decrease the voltage normally produced by the generator by independent means with the increase or decrease of load. This gives the main lift motor a definite rising speed characteristic with increase of load. The isolation of the booster winding on the generator field system renders it impossible for regenerative current to overpower the main field and allow the car to "run away." The lift motor is a shunt wound machine, the field windings of which are partially energized all the time the lift is in service. When the lift is required, the field strength is immediately brought up to full value. The armature speed is 80 r.p.m., and the driving sheave 24 in. in diameter. A speed of 3 r.p.m. is possible for levelling purposes. These figures correspond to running and levelling speeds of approximately 500 and 20 ft. per min. respectively. The brake drum and sheave are directly coupled to the armature spider without the use of keys. Each of the two brake bands is entirely independent of the other, even for spring pressure. The action of the brake is controlled, so that release is gradual whilst application takes place in two stages; the first a fairly quick action to take up the clearance, and the second a squeezing action, achieving its maximum after the car has come to rest.

The patented feature of the controller is the means employed to produce "distance" as distinct from "time" acceleration and deceleration. It is, therefore, possible to obtain equal rates of acceleration and deceleration irrespective of loads, and thus prevent waste of time by running long distances at slow speed. The equipment for achieving this consists of a multiple contactor rheostat operated by means of a camshaft which is coupled to the winding gear, and at appropriate times is made to move forwards and backwards in unison with the motion of the car, opening and closing the requisite contactors to produce smooth acceleration and deceleration of the car. All *R* contacts shown in the wiring diagram are operated by means of this mechanically driven camshaft. The *CS* contacts on the car switch are operated by movement of the car switch in either direction, whilst *CSU* contacts are operated in the Up direction of the car switch only and *CSD* contacts are operated when the car switch is moved to the Down direction.

To start the lift, the attendant presses the starter button fitted in the car, and the motor generator set automatically starts. When the signal lamp on the push button plate assumes full luminosity the field protective relay has closed circuit and the lift is ready for operation. The circuit shown is for four floors, and it will be assumed that the car is at the bottom floor and the attendant, after starting the set, moves the car switch to the Up position. The operation of the car switch completes a circuit for the close gate relay *CL* from +ve pole of exciter via *FR*1, *CSU*1, cut-off switch *COC*, *CL*, *OP*1 to

–ve. Both *CL*2 and *CL*3 close and connect the mains to the gate motor, which operates to close the landing and car gates. *COC* disconnects the circuit for *CL* when the gates have closed. If it is desired to arrest the motion of the gates when closing and to re-open them, it will be noted that this may be done by returning the car switch to the Off position and thus opening *CSU*1. When the gates are closed, the lift circuit is completed and the Up relay magnet *U* operates via +ve, starter interlock (now closed), governor switch, car stop, landing gate contacts, car gate, change-over switch, *CSU*2, coil *U*, *CSU*3, *TSU*, *ESU* (emergency stop on car), Up coil *A*, *B*1, *R*13 to –ve. The energizing of coils *U* and *A* causes all the *U* and *A* contacts to operate. Current from the exciter passes to the lift motor field via *FR* and *A*12 and to the loop switch coil *L* via *FR*1, *A*5, and *R*14. The closing of *L*1 causes the generator to give current to the lift motor armature and at the same time the brake is released on the operation of *A*6 and *A*7, and the opening of *L*2. The closing of *L*4 and *A*12 short-circuits the economy resistance which is left in circuit with the main lift motor field when the lift is at rest, and this increases the motor field strength and starting torque to their maximum values. Coil *LC* is energized via *A*10 and thus withdraws the lock cam beyond reach of the gate lock strikers until the floor at which a stop is desired is reached. The generator field is energized via *FR*1, *L*5, *A*3, *A*4, and the field rheostat. Simultaneously the accelerating magnet *AM* is fed via the change-over switch, *U*1, *CSU*6, *UD*, *SS*, coil *AM*, and *R*12. The accelerating magnet applies pressure to the accelerating clutch, and by closing *AM*1 increases the initial strength of the generator field. Contact *AM*2 also closes and energizes *R*10 ready for the operation of the camshaft. The energizing of *AM* causes the friction clutch on the right-hand side of the controller to close, and rotation is transmitted from the hoisting sheave to which the clutch is connected by a chain drive. The rheostat camshaft is therefore rotated to the full extent of its movement in unison with the car motion, and the *R* contacts are thus operated. Rheostat contacts *R*1, *R*2, *R*3, *R*4, *R*5, *R*6, *R*10, *R*7, *R*8, and *R*9 close quickly in the order given above, and the generator field strength is brought up to full value so that the motor then runs at the full speed of 80 r.p.m. After the camshaft completes its full travel the clutch is allowed to slip. *AM*4 energizes *DR* and *LW*, the latter withdrawing the levelling switch *LW*1 beyond reach of the intermediate floor cams. The operations described above take place in about two seconds, and the generator voltage induced in the armature and transferred to the lift motor increases rapidly but, due to the lag of magnetic flux, the voltage is produced in a curve devoid of steps, thus ensuring that a smooth acceleration is obtained. Contacts *R*12, *R*13, and *R*14 open and introduce economy resistances into the accelerator, reversing, and loop switch magnet circuits respectively. The demagnetizing protecting switch *R*15 on the camshaft opens in readiness to apply current to the demagnetizing winding when deceleration is completed. Interlocking safety switches *R*16 and *R*17 open in readiness to apply the automatic emergency stopping switch on the car (*ESU* and *ESD*) before the terminal levels are reached in the event of the controller failing to operate normally when approaching the stopping levels.

If a stop is desired at the fourth floor, the attendant releases the car switch after passing the third floor, and the switch automatically returns to the OFF position. The opening of *CSU*4 and *CSU*5 re-inserts resistance direct into the generator field, and the opening of *CSU*6 removes the short circuit from the intermediate slowing switch bank of the floorsetter gear. Similarly, *CSU*3 removes the short circuit from the stopping switch bank. The intermediate slowing switch between the third and fourth floors is the next switch to operate, having been set to act at the correct decelerating distance for the fourth floor. This de-energizes *AM*, and the closing of *AM*3 energizes the decelerating magnet *DM*, thus operating the two friction clutches on the left-hand side of the controller. Rotation is then transmitted from the main hoisting sheave as before, so that the camshaft is rotated in the opposite direction to that for acceleration until it arrives back at the start position. At this point the decelerating magnet is automatically de-energized by the opening of *R*1, and releases the mechanism which resets itself ready for the next operation. Thus resistance is re-inserted into the field by the opening of *R*2–*R*9 and the car speed is reduced to the levelling speed of about 20 ft. per min. The next switch to open is the intermediate stopping switch between floors 3 and 4, and this disconnects coils *U* and *A*. The opening of *A*6 and *A*7 de-energizes the brake and the consequent closing of *BS* inserts a buffer resistance to ease the action of the engagement of the shoes with the drum. Demagnetizing switch *A*2 closes, and when the motor torque is reduced to zero and the brake bands have gripped the drum, *LB* opens and cuts off *L*. This causes *L*2 to close and apply the dynamic brake. When the car finally comes to rest and all the controller contacts are in the OFF position, the lock cam withdrawal magnet *LC* is de-energized. The cam then falls into position and releases the locking gear on the electric locks, and at the same time causes the interlock switch on the lock to close. *OP* is then energized, *OP*2 and *OP*3 close, and the gate motor automatically opens the gates. When the gates are fully opened, *COO* opens and stops the motor, the gates remaining fully open.

In the event of the levelling due to the operation of the floor selector being inaccurate, it is corrected by the leveller switch *LW*1 mounted on the car. This switch is of such a design that its operation is independent within wide limits of the lateral movement of the car. Hence worn guide shoes or side motion of the car guides do not impair the accuracy of stopping and levelling. If the car levels too low, the switch *LW*1 engages the lower level of a ramp in the well and is operated in such a direction so that when *DR*1 (lagged) closes shortly afterwards when the motor has stopped, the UP coil *A* is energized via change-over switch, *U*2, *D*2, *DR*1, *CS*2, leveller cut off, *LW*1, *TSU*, *R*16, *A*, *B*1, and *R*13. This causes the car to move upwards at slow speed until *LW*1 engages with the ramp second level and is thus cut off, thereby de-energizing *A* and correctly levelling the car. Similarly the DOWN coil *B* is energized by *L*1 if the car stops too high.

The slowing and stopping switches are incorporated in the floor selector, which is situated in the motor room. This selector consists of a worm-driven shaft which is caused to rotate by the up and down motion of the car. To the car is attached a steel rope passing round a sheave direct coupled to the worm gear of the selector, and a suitable reduction in speed is introduced so that the movement of the shaft represents the car's motion on a small scale. Attached to the shaft are roller arms which engage with the quick-break slowing and stopping switches.

The operations for a down journey are similar to those described above, except that the switches involved are those in the DOWN circuits.

If the attendant omits to move the car switch to the stopping position when approaching the terminal floor, the operations for bringing the car to rest at the end of travel in a normal manner are initiated in a multiple contact switch situated on top of the car. This multiple contact switch incorporates a total of eight switches, four for each direction of travel, each switch being operated by its own cam in the well. When the car approaches, say, the top terminal landing, the UP fast-speed cut-off switch is opened by engaging with a cam in the well, and this brings about the first reduction in car speed by introducing resistance in the generator field. After travelling a short distance at the reduced speed, the UP decelerating switch on the car (*UD*) is opened by engagement with another cam in the well and thus de-energizes *AM*, which in turn releases the accelerator clutch and energizes *DM* by the closing of *AM*3. Thus additional resistance is inserted in the generator field as described above, and the slow levelling speed is reached. The terminal limit switch *TSU* on the car finally stops the car's motion by engaging a cam in the well and cutting off coils *U* and *A*. The brake operates and the car stops as described above. Emergency switch *ESU*, the fourth switch of the multiple control switch, definitely cuts off coil *A* before the terminal landing is reached, even if the other switches fail or the controller fails to respond to them and normal deceleration has not taken place.

In an emergency, momentary pressure on the car stop button de-energizes the reverser coil and the accelerator magnet *AM*, the latter causing the camshaft to be returned to the starting position under the influence of a counterweight, thus bringing the car to rest rapidly and smoothly. Failure of the main supply, unsafe weakening of the motor field, or operation of the overspeed governor has an exactly similar action.

Slow-speed switch *SS* fitted in the car permits of the operation of the car at the slow levelling speed throughout its travel to facilitate testing and inspection. This is effected by *SS* cutting off the accelerator magnet *AM*. The change-over switch fitted on the controller enables the lift to be operated from the motor room in the up or down directions at slow or fast speed by operation of the appropriate test buttons. The cooler switch fitted to the brake inserts the cooler resistance after the brake plunger has made its stroke.

AUTOMATIC CONTROLLERS

As the name implies, this type of controller is one in which the operations of starting, accelerating, and stopping the lift are performed automatically after a landing or car button has been pressed. The selection of the desired floor is effected by means of floor relays and direction switches; one relay and switch for each floor served. On pressing a car or landing button the corresponding floor relay is energized, and at the same time the main supply is connected to the motor. The floor relay is disconnected when the car reaches the desired floor and opens the direction switch.

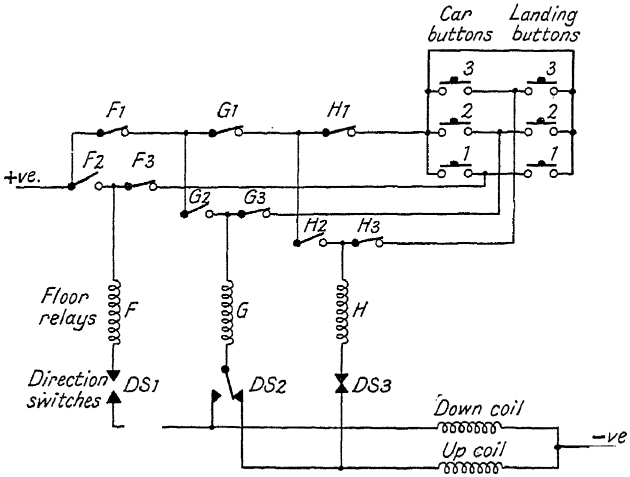


FIG. 187. ELEMENTARY DIAGRAM OF AUTOMATIC CONTROLLER

Elementary Automatic Controller. An elementary automatic control diagram for three floors is shown in Fig. 187. A single-way direction switch is required at each terminal floor, and a two-way switch at each intermediate floor. As the car passes an intermediate floor, the direction switch is changed over from the UP direction to the DOWN direction if the car is travelling upwards, and vice versa if travelling downwards. A floor selector fitted in the motor room may be employed to perform the same functions as those of the direction switches. In the diagram the car is at the bottom landing No. 1, and the direction switch $DS1$ at that floor is open. All direction switches above the car have joined their floor relays to the UP coil. If the landing button No. 3 or car button No. 3 is now pressed a circuit for the third floor relay H will be completed via +ve, $F1$, $G1$, $H1$, No. 3 button, $H3$, coil H, direction switch $DS3$, UP coil, and -ve control feed. Contact $H2$ immediately closes and a circuit for coil H is then provided from +ve, $F1$, $G1$, and $H2$, this circuit being independent of the buttons. Hence, only momentary pressure on a button is necessary to operate and lock the circuit for coil H. The opening of contacts $H1$ and $H3$ disconnects the car and landing buttons and prevents interference with the motion of the lift by the operation of any other button. When the UP contactor (not shown) operates on the energizing of the UP coil, the supply is connected to the motor and the lift begins to move. As the car travels upwards and passes floor No. 2 a ramp, fixed to the car, operates direction switch $DS2$ and causes it to make contact on the DOWN coil side, thus preparing a circuit for the down direction of travel. On nearing floor No. 3, the car ramp opens switch $DS3$, thus cutting off the circuit for the UP coil and causing the UP contactor to open. The brake then operates and stops the car at the landing. If the car had been called to floor No. 2 instead of floor No. 3, then floor relay G would have been energized and its contacts $G1$, $G2$, and $G3$ operated instead of relay H and its contacts. Operation in the down direction is similar except that the DOWN coil is energized instead of the UP coil. For example, if the car is now called down to floor No. 1, floor relay F would be energized via +ve $F1$, $G1$, $H1$, landing button No. 1, $F3$, F, $DS1$, and DOWN coil to -ve, thus operating contacts $F1$, $F2$, and $F3$.

Semi-automatic Single-speed Controller. The wiring diagram shown in Fig. 188 is suitable for a single-speed goods or service lift with two landings and UP, DOWN, and STOP buttons fitted on each landing. The supply is three-phase, and a slip-ring

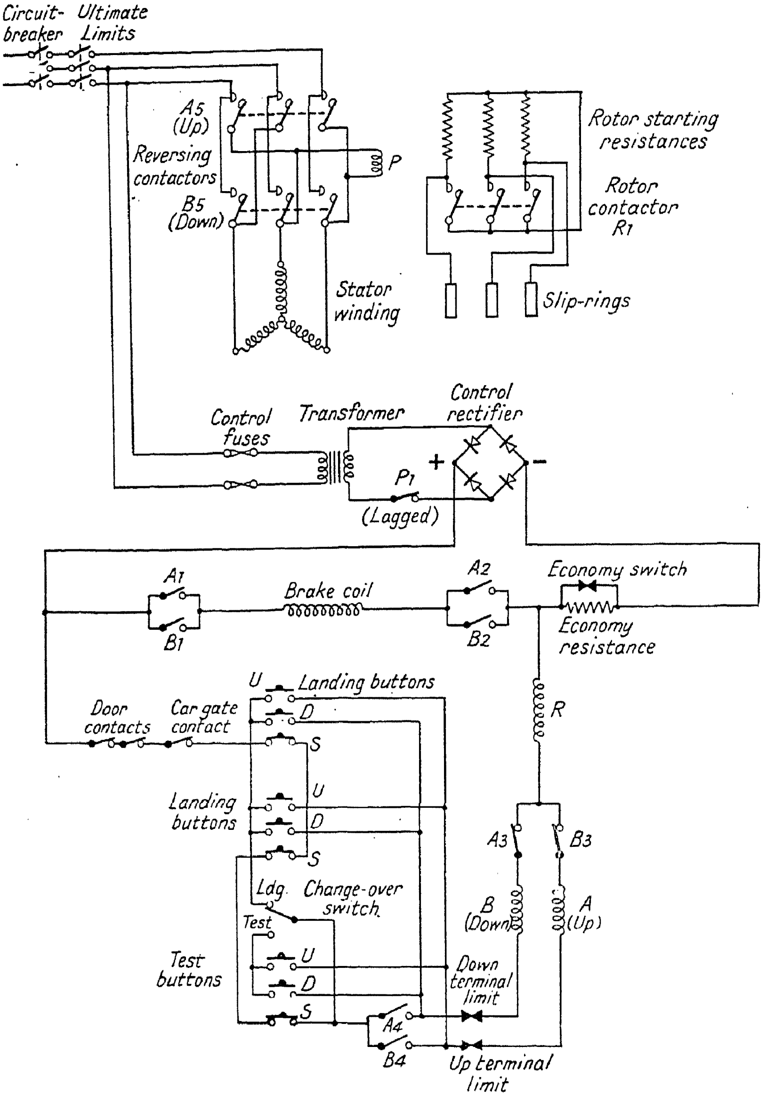


FIG. 188. SEMI-AUTOMATIC CONTROLLER FOR SERVICE LIFT

motor with one step of starting resistance is used. If the car is at the bottom landing, the operation of the circuit is as follows. The down terminal limit switch is open and it will be noted that pressure on either Down button (*D*) will have no effect as it is impossible to complete a circuit for coil *B* by operating a Down button. If an Up landing button (*U*) is pressed, the circuit for coil *A* is via +ve the door and car contacts, stop buttons *S*, change-over switch, operated *U* button, Up terminal limit switch, coil *A*, interlock *B*3, rotor contactor coil *R*, and brake economy resistance to -ve. The closing of *A*1 and *A*2 energizes the brake coil and releases the brake. Contactor *R*1 closes a few seconds later and the motor accelerates to full speed corresponding to, say, 100 ft. per min. As soon as the brake has released, the brake economy switch opens and inserts the economy resistance. When the car reaches the upper floor the Up terminal limit switch fitted in the well is opened by a ramp on the car, and the car then stops due to the de-energizing of coil *A* and the opening of contactor *A*5.

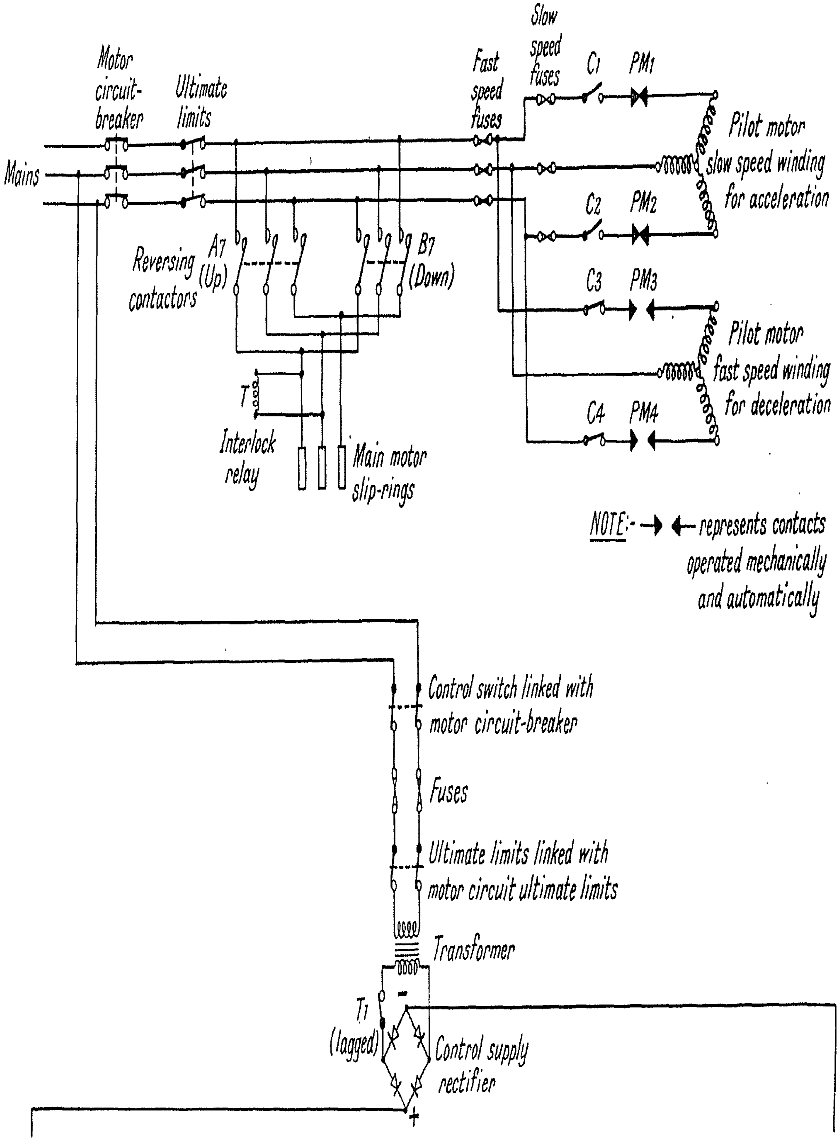
A circuit for coil *B* is similarly provided on the operation of a Down button.

The change-over switch permits of the operation of the car from the motor room by moving the switch to test and depressing a test button.

Contact *P*1 is lagged for a period of from $1\frac{1}{2}$ to 2 times of a complete journey and by cutting off the control circuit after this period so prevents the motor being connected to the mains in the event of a brake coil failure.

Fully Automatic Two-speed Controller with Corrective Levelling and A.C. Commutator Motor. The diagram shown in Fig 189 is of a controller for an a.c. commutator motor, the controller being manufactured by Messrs. Wm. Wadsworth. The control supply is d.c., being obtained from a transformer and rectifier, and in the sketch shown is separately switched from the motor circuit. The two circuits are protected by a five-pole ultimate limit switch, whilst the control switch is linked to the motor circuit breaker. Hence the two circuits may be operated independently of each other for test purposes by removing the link, whilst during normal operation the control circuit is broken if the circuit-breaker operates.

The levelling switch *L*1 is mounted on the car and engages



NOTE:- → ← represents contacts operated mechanically and automatically

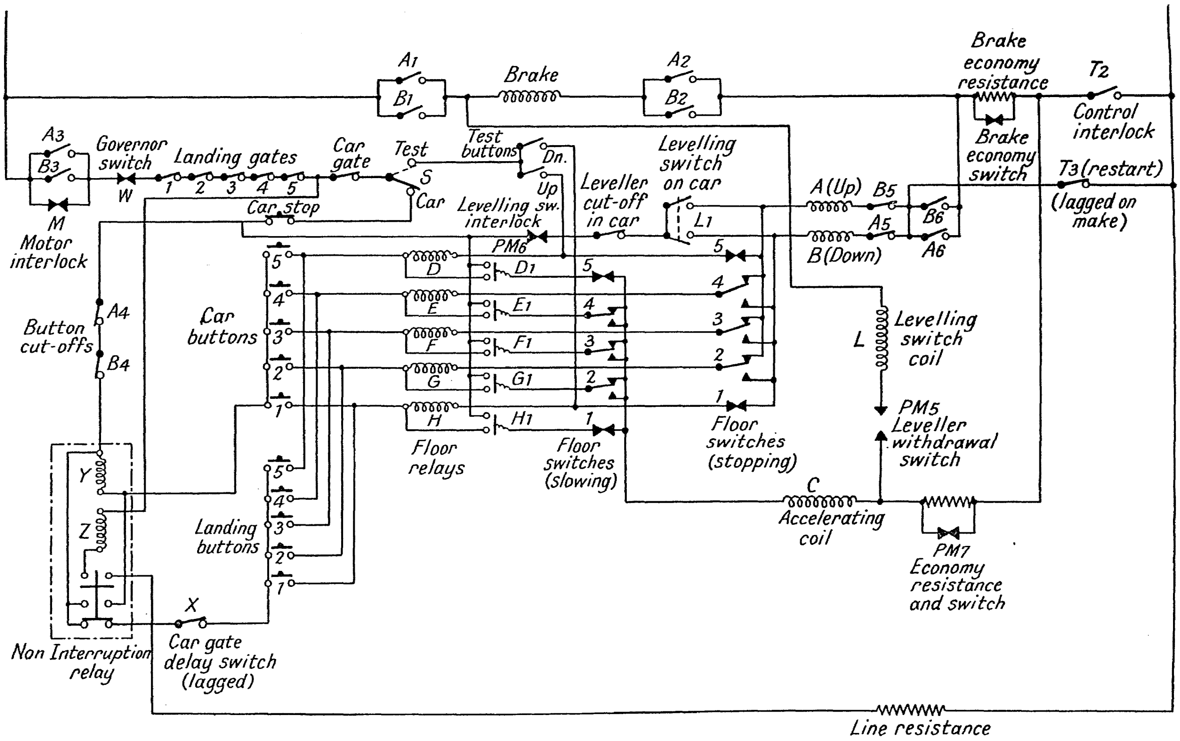


FIG. 189. TWO-SPEED AUTOMATIC CONTROLLER WITH A.C. COMMUTATOR MOTOR AND CORRECTIVE LEVELLING

with a specially shaped aluminium ramp, one being fitted at each landing. The ramp has three levels, the levelling switch engaging with the centre level if the car is correctly levelled and then remaining open. If the car comes to rest below the landing, the switch engages with the bottom ramp level and this causes *L*1 to operate in such a direction that coil *A* is energized, the Up contactor *A*7 is operated, and the car moves upwards at slow speed. Similarly the upper ramp level is engaged when the car rests too high and *L*1 is operated in the opposite direction, thus energizing *B*, operating contactor *B*7, and causing the lift to travel down until the centre level is engaged and the car correctly levelled.

The brush operating pilot motor is a two-speed squirrel-cage motor, the slow-speed winding being used during the accelerating period and the fast-speed winding during deceleration when driving the brushes back to the slow-speed position. The pilot motor drives a worm reduction gear, thus giving suitable speeds at the main shaft for accelerating and decelerating. The worm gear shaft is direct coupled to a drum shaft through a continuous pressure friction clutch, so that when stops on the drum shaft come into engagement, the motor can still travel onwards a little without danger of breaking anything. On this drum shaft are cams which engage with small switches, four of which act as cut-offs for the pilot motor, the others performing separate functions. These small mechanically operated switches are marked *PM* in the diagram. The travel of the drum shaft is approximately 120°, and attached to this on opposite sides are two chains which are in turn fastened to the brush rocker gear of the main motor. These chains are linked together by extensions of the chain taken over a pulley. The brush operating gear is therefore positively driven both forwards and backwards.

The circuit shown is for five floors, and in describing the operation it will be assumed that the fast running speed is 350 ft. per min. and the slow levelling speed 50 ft. per min., thus giving the motor a speed range of 7 to 1. If the car is at the bottom landing No. 1, and the landing button No. 5 is pressed, the circuit for the Up coil *A* is from +ve control feed, *M*, *W*, landing gates, car gate, switch *S*, car stop button, *A*4, *B*4, bottom contact of interruption relay, *X*, No. 5 landing button, floor relay *D*, stopping switch No. 5, coil *A*, *B*5, and *T*3 to –ve. Contactor *A*7 now operates and connects the mains to the motor slip-rings. Relay *T* is energized and the closing of *T*2 and *A*6 transfers the feed of *A* via *A*6, brake economy switch, and *T*2. *A*1 and *A*2 energize the brake coil and this releases the brake, after which the brake economy switch opens and inserts the economy resistance. The closing of *D*1 transfers the +ve feed for coils *D* and *A* direct to the car stop button, thus enabling landing button No. 5 to be released immediately after depression. The opening of *A*4 cuts off the feed to the remaining buttons. A parallel +ve feed from the car stop is provided for coil *C* via *D*1, slowing switch No. 5, coil *C*, *PM*7, and *T*2. Contacts *C*1 and *C*2 close and thus supply the pilot motor slow-speed winding to drive the brushes forward and accelerate the main motor. Interlocks *C*3 and *C*4 open and guard against the fast-speed winding being energized. *PM*3 and *PM*4 close as soon as the brush operating gear commences to move, thus resetting the pilot motor for winding back as soon as it has left its starting position. When the brushes reach the full-speed position, *PM*1 and *PM*2 are opened mechanically. The lift is now running at its maximum speed of 350 ft. per min. Contact *PM*5 closes and energizes *L* via *A*1, *PM*5, *PM*7, and *T*2. The levelling switch *L*1 is thus withdrawn beyond reach of any intermediate floor ramps. When the maximum speed is reached, *PM*7 opens and inserts the economy resistance. *PM*6 also opens and ensures that *L*1 cannot feed coil *A* until the slow speed has again been reached during deceleration.

When the car nears landing No. 5, the slowing switch No. 5 is opened and coil *C* cut off. Contacts *C*1 and *C*2 open and *C*3 and *C*4 close, the latter two feeding the fast-speed winding of the pilot motor which then drives the brushes back to the slow-speed position. The car now commences to decelerate and reaches the landing speed of 50 ft. per min., when the brushes arrive at the slow-speed position and *PM*3 and *PM*4 are opened. The opening of these contacts cuts off the supply to the fast-speed winding. *PM*5 opens and the levelling switch *L*1 advances ready for engaging the ramp at floor No. 5, whilst both *PM*6 and *PM*7 close. Contacts *PM*1 and *PM*2 close ready for restarting. When the car is still nearer to floor

No. 5, the stopping switch No. 5 opens and this cuts off the feed to coils *D* and *A*, and the contactor *A*7 opens and disconnects the motor. If, on the application of the brake when *A*1 and *A*2 open, the car has correctly levelled itself, the switch *L*1 will have fallen into the centre level of the ramp. This causes *L*1 to remain open. If the car is low, the bottom ramp level is engaged and *L*1 operates in the direction which will energize the UP coil *A*, this causing the car to travel upwards at the slow speed of 50 ft. per min. until correctly levelled. Similarly, if the car is high, *L*1 operates in the opposite direction and feeds coil *B* to bring the car down to the proper level.

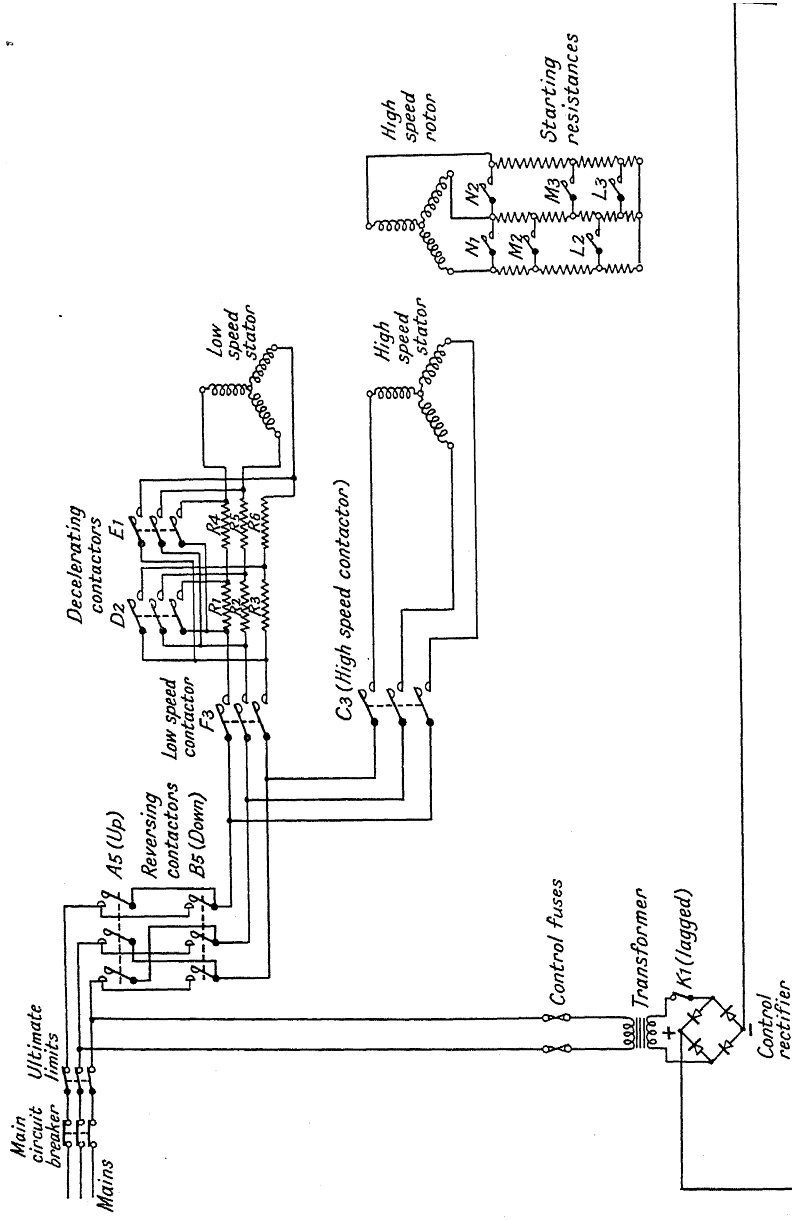
During the upward journey the motion of the car causes the floor switches to close in the opposite direction as each floor is passed. Thus, when the car is at the top floor, all slowing switches have been connected to the DOWN coil *B*, thus preparing the circuits for the down direction of travel. If any button below floor No. 5 is now pressed to bring the car downwards a circuit will be formed as above, through the corresponding floor relay and the DOWN coil *B* instead of coil *A*.

Operation from one of the car buttons is somewhat different and brings the non-interruption relay into circuit. With the car at the top floor and a person entering the car and closing the gates, it will be seen that contact *X* on opening disconnects the landing buttons for a period of about five seconds. If the passenger does not operate a car button within this period, *X* closes and the car may be called from any other landing. Assuming the passenger presses car button No. 2 within five seconds after closing the gates, the circuit through the DOWN coil *B* is via *M*, *W*, landing gates, car gate, *S*, car stop, *A*4, *B*4, coil *Y*, car button No. 2, floor relay *G*, DOWN contact of floor stopping switch No. 2, coil *B*, *A*5 and *T*3. The energizing of coil *Y* causes the contacts of the non-interruption relay to rise; the bottom pair is broken and the landing buttons therefore cut off, the second pair is made and the top pair is also made, the latter providing a holding circuit for the relay through coil *Z* and line resistance direct from the landing gate contacts. Slowing and levelling are performed as described above and the non-interruption relay is released when the landing gate No. 2 is opened. The second pair of contacts on the relay allows of the car being sent from floor No. 2 to another floor by operation of the car button after the car has stopped, and before the landing gate is opened. The relay therefore gives the person in the car sole control until a landing gate is opened and afterwards closed.

*T*1 is the control supply time lag contact and is lagged for $1\frac{1}{2}$ to 2 times a complete journey. *T*3 is also lagged for a few seconds on make only and prevents the restarting of the motor until it has come to rest. *M* is a contact on the motor, mechanically operated by the brush-operating gear, and opens immediately the brushes leave the slow-speed position and close when they return. Hence, if after the motor has stopped and *A*3 and *B*3 are opened, it will be impossible to start if the brushes have not been returned to the slow-speed position. The change-over switch *S* and the test buttons fitted on the control panel in the motor room permit of moving the car at the slow speed for test purposes.

Fully Automatic Two-speed Controller with Tandem Motor. The diagram shown in Fig. 190 is for an *automatic* controller with the car operating between five floors. A two-speed tandem motor is employed and the controller is suitable for car speeds up to about 350 ft. per min. Starting and full-speed running are performed on the high-speed slip-ring section, whilst the slow running speed of, say, one-sixth the fast speed is obtained from the squirrel-cage section.

If the car is at the bottom landing and the top landing button No. 5 is pressed to bring the car to that floor, the circuit for the Up contactor coil *A* is via landing gate contacts, car stop button, car gate contact, change-over switch, *V*1, *W*1, *X*1, *Y*1, *Z*1, *J*1, *S*, landing button No. 5, *V*2, floor relay *V*, No. 5 stopping switch, coil *A*, and interlock *B*1. Contact *A*1 on opening ensures that *B* cannot operate, whilst *A*3 and *A*4 on closing energize the brake coil and release the brake. Coils *H*, *J*, and *K* are also fed by contacts *A*3 and *A*4. The opening of *V*2 and closing of *V*3 transfers the feed of coils *V* and *A* from the change-over switch direct to floor relay *V*, thus cutting out the buttons and preventing interference when the car is in motion. The closing of *V*4 provides a parallel circuit for the high-speed relay *G* via *V*4, slowing switch No. 5, and slow test button. Contact *G*1 opens and guards against the low-speed contactor *F*3 operating, whilst *G*2 closes and provides a circuit for *C*


Main circuit breaker
Mains
Ultimate limits
A5 (Up)
Reversing contactors
B5 (Down)
Low speed contactor
F3
Decelerating contactors
D2
E1
R1
R2
R3
R4
R5
R6
Low speed stator
C3 (High speed contactor)
High speed stator
High speed rotor
Starting resistances
N1
N2
M2
M3
L2
L3
Control fuses
Transformer
K1 (lagged)
+
−
Control rectifier

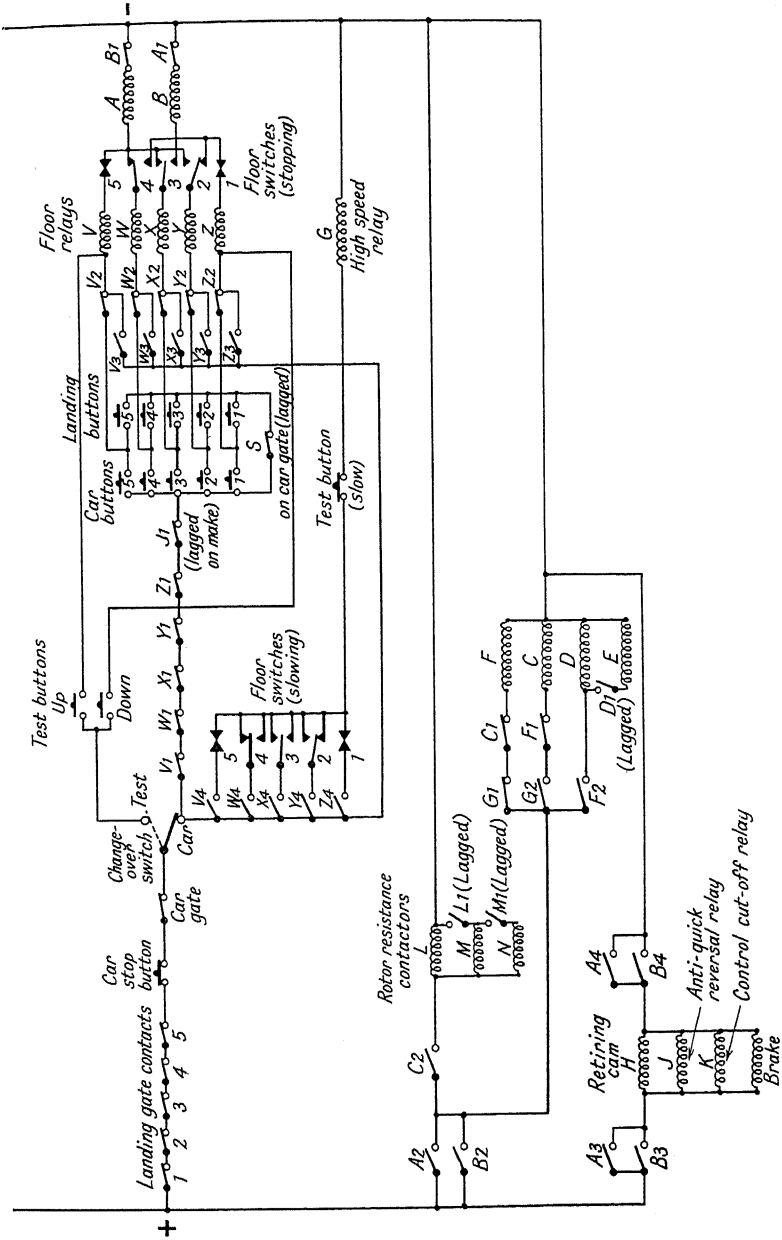


FIG. 190. TWO-SPEED AUTOMATIC CONTROLLER WITH TANDEM MOTOR

via *A*2, *G*2, and *F*1. Reversing contactor *A*5 has operated, and with the energizing of coil *C* contactor *C*3 closes and the mains are then connected direct to the high-speed stator, thus causing the motor to rotate. The closing of *C*2 provides a circuit for the first rotor contactor coil *L*, whilst *L*2 and *L*3 cut out the first step of rotor resistance. After a brief interval *L*1, which is lagged, closes and energizes *M*, thus causing *M*2 and *M*3 to cut out the second step of rotor resistance. Similarly, *M*1 provides a circuit for *N* so that *N*1 and *N*2 cut out the last step of resistance and the lift attains its full speed of, say, 300 ft. per min.

When the car approaches floor No. 5, slowing switch No. 5 of the floor selector is opened automatically. This cuts off the supply from coil *G*, and the opening of *G*2 disconnects the high-speed coil *C*, with the result that contactor *C*3 opens. The closing of *G*1 energizes *F*, and contactor *F*3 closes, thus connecting the mains to the low-speed stator via buffer resistances *R*1–6. On closing, shortly afterwards, *F*2 feeds coil *D*, and contactor *D*2 short-circuits the first steps *R*1, *R*2, and *R*3 of the buffer resistance. *D*1 is slightly lagged, and on closing energizes coil *E*, and thus the second steps of buffer resistance *R*4, *R*5, and *R*6 are short-circuited. Alternatively, these resistances may be short-circuited by a single magnet as shown in Fig. 49. The lift is now running at the slow levelling speed of, say, 50 ft. per min. On approaching still nearer to floor No. 5, the stopping switch No. 5 is opened and thus disconnects coil *A*, which in turn causes contactor *A*5 to open. The supply is now cut off from the slow-speed section and the opening of *A*3 and *A*4 causes the brake to operate and the car to level at the floor.

Operation in the down direction is similar to that described above, except that coil *B* is energized and contactor *B*5 operated instead of *A*5.

The up and down test buttons enable the car to be operated from the motor room either at fast or slow speed, the latter if the slow test button is also operated.

Various protective and non-interference devices may be incorporated in the controller. In the diagram shown, *H* is the retiring cam coil and is energized when either the UP or DOWN contactor operates, and by withdrawing the cam on the car beyond reach of the gate lock striker prevents a landing gate being "snatched" open as the car passes. The coil releases the cam when the reversing contactor opens. Contact *J*1 on the main control feed is lagged on make for a period of a few seconds; sufficiently long to enable the motor to come to rest after the reversing contactor has opened, and this prevents the motor being reversed before it has stopped rotating. The control cut-off contact *K*1 disconnects the control supply if the motor is connected for a period of more than about 1½ times a full journey. Associated with the car gate contact is a contact *S*, lagged for about five seconds, and this disconnects the landing buttons for this period after a passenger has entered the car. The ultimate limits cut off both motor and control circuits in the event of the car over-travelling the terminal landings.

CHAPTER XVI

MAINTENANCE AND TESTING

It is essential that a lift should receive proper periodical maintenance in order to obtain good service and to prevent the possibility of accidents to passengers. The inspections and tests should be performed by a qualified engineer, thoroughly acquainted with the mechanical and electrical details of the lift he is called upon to maintain. It is not sufficient to leave a lift in the hands of the "electrician," who is probably more acquainted with renewing fuses and removing faults from lighting and power circuits. If the services of a qualified lift mechanic are not available, it is recommended that the periodical maintenance be undertaken by a firm of lift engineers, preferably the makers of the lift. Almost all the reputable lift manufacturers have schemes whereby they carry out periodical inspections on lifts, for a comparatively small charge, and after each inspection submit to the owner a complete test report showing the condition of the lift. In fact, most firms would prefer this method of maintaining their own lift. Usually these standard inspections are carried out each month, during which time any necessary oiling is performed, adjustments made and, in addition, recommendations are made regarding any item of equipment, such as ropes, which require renewal. By this means the owner is informed of the condition of his lift or lifts every month and he is thus given an opportunity of remedying any defects before damage is done to the equipment or accidents occur to passengers.

The methods adopted by lift engineers for detecting faults, and the order of procedure in carrying out these tests vary, but the main items requiring inspection and means of curing troubles will be discussed.* It is, of course, not necessary to perform all the tests detailed below during each visit. To carry out a thorough inspection the mechanic must have the assistance of a mate.

Switches and Fuses. The motor room is probably the best and most usual place in which to commence an inspection, and before any testing is done the main switches for both motor and control circuits should be switched off. Although an electric shock from a low voltage may not normally be dangerous, it may cause one to jump suddenly and come in contact with a moving part of the equipment which might result in serious consequences. The size of the motor fuses and the setting of any circuit-breakers should be checked against the name-plate rating of the motor. The carrying currents of the motor fuses will vary from twice to five times full load, depending upon the type of motor. The control circuit current will generally not exceed about five amperes.

---

* See *Lift Maintenance Manual*, issued by Messrs. Marryat & Scott.

Motor. On examining the motor it will be noted that the end of the shaft is squared, the object being to allow of the insertion of a winding handle so that the car may be moved, in cases of emergency, or after overrunning a terminal landing and operating the ultimate limit switch. Before the motor can be turned by hand, however, it is necessary to release the brake. This is done either by turning the brake hand release lever which is fitted to some brakes, or by wedging the shoes apart with a piece of wood. If the need for using the winding handle arises, care must be taken afterwards to remove the handle and either reset the brake hand release or remove the wooden wedge. On some lifts an interlocking contact is fitted to the brake hand release which, by disconnecting the control circuit, prevents the restarting of the lift until the release has been returned to its normal position. The commutator or slip-rings and brushes should be examined to make sure that the latter are making good contact, and are renewed before undue wear takes place. If plain bearings with ring lubricator are fitted it should be noted whether the oil is at the correct level and whether any leakage is occurring at the drain plug, tap, or oil gauge. Ball or roller bearings are packed with grease by the makers, and replenishment is only necessary about every six months, when a little pure vaseline should be used. Excessive wear of the bearings can often be detected by a distinct knock, and results in undue strain being placed on the coupling and the worm gear bearings.

Brake. The next items are the brake and the coupling upon which the brake usually operates. The coupling should be examined to ensure that the bolts are tight and that the keys joining the shafts on each side are not loose. If the motor winding handle is inserted, and turned in each direction, looseness of the key on the motor shaft can be detected. Similarly, the key on the worm shaft may be observed, but in this case the brake must be released. Particular attention should be given to the adjustment of the brake, as an incorrectly adjusted brake will cause faulty floor levelling. When the design permits, each half should be adjusted independently so that the clearance of each shoe is the same. The clearance between the brake linings should be as small as possible, and will be found in practice to be between $\frac{1}{100}$ in. and $\frac{1}{64}$ in., if correctly adjusted. Next adjust the solenoid plunger so that the maximum possible pull is obtained. This is the case when the reluctance of the magnetic circuit is as small as possible and the maximum number of lines of force is present in the air gap. Under these conditions the brake should just operate when the magnetic circuit closes. The spring pressure should then be adjusted until smooth and rapid stopping are obtained; the actual stopping distance will vary with the car speed. After the brake has set, the car travel should not exceed about four inches for each 100 ft. per min. of running speed. The operation of any emergency brake gear should also be examined.

Gearing. The gearing is adjacent to the brake and will probably suggest itself as the next item for inspection. Examine the level of the oil in the gearbox which, if the gear is of the under-type, should be sufficiently high just to cover the worm. If the over-type gear is employed, the level should be about four inches above the bottom of the worm-wheel. The gear oil recommended by the makers should be used, but if this is not available, pure castor oil may be substituted. As in the case of all gearing, however, the mixing of oils in the gearcase is not recommended. The gearcase should be examined for leaks and tightened where necessary, and if the gland is showing signs of leakage, the gland nuts should be tightened up in rotation. Wear of the gear teeth can be detected by removing the gearbox cover and turning the motor by hand. Another method of detecting wear entails loading the car until the lift is balanced, and then, by overbalancing one side, a movement of the worm-wheel will indicate excessive wear of the teeth. The fixing of the worm-wheel rim to its centre should be carefully examined. A double thrust race is usually fitted at the outer end of the worm shaft to accommodate the worm thrust in both directions of travel, and an inspection of this thrust race is necessary to ensure that excessive wear has not taken place. If undue wear is present, the thrust is likely to be transferred to the motor bearings, which may overheat and cause a break-down. Wear may be compensated for by removing the thrust and making adjustment.

Sheaves and Pulleys. An examination may next be made of the sheave or drum and any diverting pulleys to detect whether any looseness on the shafts is present due to keys working loose. Play may be detected by observing the line of contact of the sheave and its shaft when the lift starts or stops, and the "bubbling" of a little oil placed around the line of contact will clearly show any relative movement between the sheave or drum and the shaft. If looseness is present, the key should be driven in tightly, but it may be necessary to fit a new key. With a traction drive, the sheave grooves should be examined for wear, and if ridges are present in the grooves these may, in time, cause rope slip which will result in rope wear. Rope slip may be detected by chalking the rope and sheave, and after the lift has made a few journeys, again examining the marks, which should still coincide. In addition to worn grooves, excessive use of lubricant on the ropes may be responsible for rope slip. In the former case the remedy is removing the sheave and having the grooves re-cut, whilst in the latter, removal of the excessive oil with a paraffined rag will cure the trouble. If the ropes "bottom" in the grooves, slip may again result and it is then necessary to fit larger ropes. It should also be noted whether the ropes lead on and off the sheave without binding on the sides of the grooves. The presence of a crack in the sheave, drum, or diverting pulleys may be detected by hammer testing.

Controller. The controller may now be inspected, and in carrying this out more good will probably result from a very careful visual inspection than anything else that may be done. Loose, disconnected, or short-circuited wires are frequent sources of trouble, whilst if stranded wire is used on any contactors, this should be examined for broken strands which may cause a breakdown in the near future. Badly burned contacts should be cleaned and if necessary adjusted. The contacts are copper-to-carbon or copper-to-copper, and in the latter case, if cleaning is necessary, care must be taken to ensure that any "roll" incorporated in the design is not reduced or destroyed. If this is done, welding of the contactors may result. When an appreciable amount of cleaning or filing of contacts is necessary, the profile of the contacts should be tested with a template having the same curvature as a new contact, before the contacts are replaced. The mechanical interlock between the reversing contactors should be examined if such an interlock is fitted. The pins on which the various contactors operate should be perfectly free and should occasionally be given a drop of thin oil. Careful inspection of any controller dashpots is necessary to ensure that they provide the time lags intended. It is important to use only the type of dashpot oil recommended by the makers, or the settings will become inaccurate. An electrical insulation test should be taken on motor and control circuits at a voltage of 500 volts d.c. and when taken from the main switch with all coils in circuit should not be less than 1MΩ.

Floor Selector. Now that the brake has been correctly adjusted, an inspection may be made of the floor selector gear if the lift is automatically controlled, and any necessary adjustments made. The operation of each striker arm and its associated switch should be examined to see whether the best possible levelling is obtained at each floor. Commencing with the up direction switch contacts, the lift should be called up from the bottom floor to the next floor, with no load in the car. The lift should level slightly high, say $\frac{3}{4}$ in. After measuring this distance, call the car up to the next floor and take a similar measurement of the distance that the lift stops above this floor. After this has been done, repeat the tests but with full load in the car, and in these cases the lift should stop a small distance below each floor. If necessary, the striker arms on the selector should be adjusted so that the stopping distances above the floors, when light, and the stopping distances below the floors, when carrying full load, are all equal. This adjustment will provide the best average levelling in the up direction for all loads if the counterweight is equal to the weight of the car plus 50 per cent full load. Hence, with 50 per cent full load, accurate levelling in the up direction should be obtained. If, however, the counterweight is, say, equal to car plus 40 per cent full load, it will be necessary for the car load during the load levelling test to be equal to 80 per cent full load instead of full load. This will ensure that correct levelling is obtained in the up direction with 40 per cent full load in the car. The strikers operating the down direction switches must be adjusted in a similar manner to that for the up switches, but with the car travelling in the down direction. During these down direction tests it will be noted that the empty car will again level high and the loaded car low. When a two-speed motor is employed, the floor selector will have slowing switches fitted for each direction in addition to stopping switches. The slowing switch strikers should be adjusted so that the lift speed is reduced to the low-speed value before the stopping switches are operated and the brake applied.

If stopping and levelling are performed by direction switches in the well and a cam is fitted on the car (see Figs. 165 and 166), instead of a floor selector in the motor room, it will be necessary, in order to check the levelling, to take measurements at the floors after stopping the lift at each floor when travelling up empty. Adjustments should be made to the positions of the switches (except the ground floor switch) so that the stopping distances above each floor are equal. Similarly, the position of the ground floor switch should be adjusted until the stopping distances below each floor are equal when the car travels down loaded. If the actual distance in the well between the up and down stopping points at each landing is now made equal to say, $1\frac{1}{2}$ in., i.e. $\frac{3}{4}$ in. above the landing and $\frac{3}{4}$ in. below the landing, then levelling to within $\frac{3}{4}$ in. will be obtained. For example, if the up empty levels were all $1\frac{1}{2}$ in. high, and the down loaded levels all $\frac{1}{2}$ in. low, the top horn on the cam must be raised by $\frac{3}{4}$ in. and the bottom horn raised $\frac{1}{4}$ in. When the switches and cam have been adjusted, the only reason for inaccurate floor levelling will be that the brake is out of adjustment. It will probably be found more convenient to test these direction switches, when fitted, after the motor room inspection has been completed.

Ultimate Limit Switch. This should be occasionally tested by holding in the appropriate controller contactors and allowing the car to operate the switch after over-travelling each terminal landing in turn. The ultimate limit switch is usually operated by a striker on the car engaging with a stop on the limit switch operating rope, one stop being fitted for each terminal landing. The overrun, after passing the terminal floor and before the limit switch operates, may be adjusted by altering the position of the rope stop. Two paint marks on the operating rope or pieces of adhesive tape are often used to indicate that, when the marks are opposite each other, the rope stops are in their correct positions in the well.

Governor. The overspeed governor must be lubricated where necessary and kept clean. During inspection the weights should be operated by hand to see that, firstly, the control cut-off switch operates, and secondly, the governor gripping jaws are released and grip the governor rope.

Motor Generator Set and Compressor. With variable voltage equipment, an inspection of the motor generator set is necessary, and if pneumatic door operating gear is installed, attention should be given to the air compressing plant, which will probably be located in the motor room.

Ropes. Before leaving the motor room, a careful visual examination should be made of those portions of the lifting ropes which pass over the sheave or drum during a complete journey of the lift. Any "needling" of the ropes, i.e. broken wires, should be carefully noted; the detection of these "needles" being greatly facilitated by the aid of a small mirror used for the underside of the ropes or by a wad of cotton waste held lightly against the ropes. The presence of a few broken wires does not indicate that the rope should be immediately renewed, as the factor of safety is usually about 15, but rather that the ropes should be kept under careful observation during subsequent visits. It is very difficult to quote any rule for determining when ropes should be renewed as cases have occurred of ropes failing when no broken wires have been visible, and others when the rope has given long service after a comparatively large number of wires have been broken. The decision to renew a rope rests largely upon the engineer's experience and is usually governed by the number of adjacent broken wires. Undue rope stretch is another indication of approaching rope failure.

When rope renewal is considered necessary, careful measurements must be made to ascertain the length and size of rope required. Due allowance must be made for wear and stretch of the old ropes in determining the correct rope size, and usually the measured diameter of the old ropes will lie between two standard sizes. The larger of the two sizes will invariably be the correct size of rope required, the specified size being that of the circumference of the circumscribed circle. Rope fastenings are made either by sockets, splicing, or the use of bull-dog grips, and in some circumstances it may be preferable for the splices to be made before the rope is delivered, whilst in others these could more conveniently be made during fixing, providing a qualified splicer is available. During re-roping, care must be taken to bind the ends of the ropes before cutting (unless preformed ropes are used) to prevent unravelling. The actual method adopted for re-roping will depend upon the type of lift and other local conditions, but it is usually possible to position the car at the top landing so that the car top is accessible from that landing, and the bottom accessible from the landing below. When in this position, the counterweight is supported by a wooden prop in the well bottom. The car is next raised a few inches by means of lifting tackle and all is in readiness for removal of the old ropes and fixing of the new ones. The worn ropes may conveniently be used for towing the new ropes into position by temporarily fixing the former to the latter. Oil should not be used on the lifting ropes unless the lift is in a damp location, when a little may be applied to prevent rusting of the ropes.

General. When the motor room is located in the basement, attention must be given to the lubrication of the overhead diverting pulleys. With an automatic lift, the landing buttons may be tested by calling the lift to each landing in turn, and with a car switch lift, by noting that the pressing of each button gives the correct signal on the car indicator. When on the landings, the operation of the landing indicators should be checked and the door and gate locks tested. It must be verified that the car will not move with any landing or car gate open and ascertained whether the landing gates or doors can be opened without lifting the releasing levers. Note how far the doors are open when the interlock closes and the car starts when automatic door closers are fitted. When a retiring lock release cam is installed, it should be impossible to snatch open a landing gate when the car passes that landing. Collapsible gates must be lightly lubricated at the joints and the tracks cleaned. The inside of the car, including car switch or push buttons, emergency handle, and any car floor switches may next be conveniently examined. Floor switches are a frequent source of trouble and require careful examination and cleaning during each visit. If the false floor sticks down, it will be impossible to call the car from the landings, whilst if contact is not made, interference can occur from landings when the car is occupied.

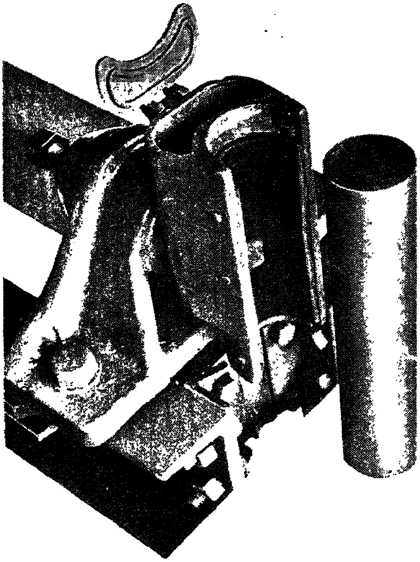


FIG. 191. GUIDE LUBRICATOR
(Marryat & Scott)

From the top of the car, inspections may be made of the rope fastenings and equalizing gear, governor rope release, guides and guide shoes, any electrical door operating gear, retiring cam mechanism, and counterweight rope fastenings. Steel guides should be periodically lubricated with medium machine oil, although automatic guide lubricators using heavy oil are often fitted to the guide shoes; but these obviously require replenishing at intervals. An automatic guide lubricator fitted to leather lined shoes running on a round steel guide is shown in Fig. 191.

The remaining inspections can be carried out from the bottom of the well. These include the buffers, ultimate limit switch pulley, safety gear, and bottom guide shoes. Attention can conveniently be given to the above items if the car is lowered to within, say, six feet from the pit bottom. If piston type buffers are fitted, see that the oil is at the correct level. It is most important that the car safety gear be carefully examined, cleaned, and lubricated and afterwards tested by hand to ensure that tension on the safety rope will operate the cams or wedges. At intervals of, say, six months, it is desirable that cam safety gear be operated by hand, with the car stationary, and the car then lowered to ensure that the gear functions correctly. Frequent operation of the safety gear from full speed, during testing, is to be avoided as damage to the car or guides will most likely result, the latter particularly with the cam type gear. Rope compensation gear may also be inspected from the pit bottom.

ACCEPTANCE TESTS

Before a new lift is taken over from the manufacturers and put into commission, certain essential tests should be performed to ensure that the lift is satisfactory and conforms to the conditions laid down in the specification. The acceptance tests usually performed are detailed below.

It is desirable that the manufacturers supply and fix in the motor room a framed and glazed wiring diagram of the lift connexions for the use of the maintenance engineer, together with any maintenance recommendations which they wish to make. A plate should be fixed in the car showing the maximum car load, and in the case of passenger lifts, the maximum number of passengers to be carried, calculated at not less than 150 lb. per passenger. The actual requirements of different purchasers vary in detail, and if the lift has been manufactured and installed in accordance with a specification, it is necessary that those acceptance tests should be performed which will confirm whether the clauses of the specification have been fully met. In some instances the actual tests which will be applied are stated in the specification. Before carrying out any specified tests, the lift should be carefully examined and checked against the general requirements as regards type of equipment, construction of car and gates, type and fixings of guides and shoes, position of safety gear and buffers, methods of guarding, indicators, and other general items. After this has been done, the tests called for may be performed.

Dead Load Test. Frequently the equipment is required to sustain a load on the ropes equal to twice the maximum dead load borne in practice, for a period of about half an hour without showing signs of permanent distortion. It is desirable that this test be performed first so that any defect caused by weakness may possibly be revealed during subsequent tests. The car gate and landing gate leading pickets should be placed side by side and a horizontal line drawn on the leading edge of each picket, the car, during this operation, being stationed at the ground floor. The car should be loaded with standard weights of such value that the load in the car is equal to the weight of the car plus twice the maximum rated load. On removing these weights, after the specified period, the amount of permanent set will be indicated by the vertical distance between the lines on the car and landing gate pickets. This set should not generally exceed $\frac{1}{8}$ in. to $\frac{1}{4}$ in. If the permanent set is abnormal, it may be traced to faulty rope fastenings or rope slip on a traction drive lift. It is a good plan to mark the lifting ropes and the sheaves before applying the weights, and thus any rope slip on the sheave can readily be detected after the test.

Energy Consumption. Maximum rated load is required in the car for this test, and an energy meter connected in the supply to the lift, in such a manner that it indicates the sum of the motor and control consumptions. The consumption for a complete up and down journey is very small, and it will be necessary to take the average of, say, five complete journeys to obtain a reliable reading on the meter. When the marked rotating disc of the meter is visible, however, it is often possible to obtain the consumption for a complete journey by counting the number of revolutions made, and applying the ratio stamped on the meter. Excessive consumption may be accounted for by an inaccurate counterweight value.

Full Load Levelling. If the lift is equipped with automatic control, the accuracy of the floor setting gear may now be tested under full load conditions without altering the car loading from that used during the energy consumption test. The car should be called to each floor in turn when travelling in the up direction, and the actual distance that the car stops below each floor measured. Similarly, the stopping distances below each floor on the downward journey must be measured. These distances will be compared with the corresponding measurements taken later when the car is empty.

Irreversibility. Some authorities specify that their geared lifts must be self-sustaining and this may be checked by cutting off the control circuit and releasing the brake by hand, when the car, with full load, should remain stationary.

Safety Gear Tests. With the maximum load still in the car, the safety gear may now be tested. If the lift operates from a d.c. supply, the excess speed necessary to operate the gear may be obtained by field weakening, but if an a.c. motor is installed the gear may be set to operate at the maximum car speed or alternatively tripped by hand at the maximum speed. Sometimes the governor sheave is provided with an extra groove of such a size that it will permit of the governor being driven at a speed corresponding to the safety gear tripping speed when the lift is travelling at its normal maximum speed.

Maximum Speed. This should be measured with maximum load in the car, the most convenient method being by counting the number of revolutions made by the sheave or drum in a known time. A chalk mark on the sheave or drum and a stop watch will facilitate counting and timing, but care must be exercised to ensure that no acceleration or retardation periods are included.

Car Emergency Handle. The total load in the car should be the maximum load so that the weights will be equal to the maximum car load less the weight of the operator. When the car has reached its maximum speed, the pulling of the handle should cut off the main and control circuits, by operating the ultimate limit switch, and the brake should then bring the car to rest within a few inches.

Lift Balance. Some of the weights should now be removed until the remaining represent the balance figure specified, say, 50 per cent maximum load. It should now be ascertained whether the counterweight is equal to the weight of the car plus 50 per cent maximum load. This may be roughly checked by cutting off the supplies and rotating the winding handle in each direction in turn, and the effort required should be, as nearly as can be judged, the same. A more accurate test consists of wiring an ammeter in the motor supply and taking current readings during the upward and downward journeys. If the lift is properly balanced, these readings should be the same for each direction.

The remaining tests may be taken with no load in the car.

Levelling Empty. If the lift is automatically controlled, the car should be stopped during the upward journey at each floor in turn, and the stopping distances above each floor measured. The "up" levelling gear is correctly adjusted if these "high" distances are approximately equal to the "low" distances obtained during the up full load levelling test. Similar figures must be obtained during the down empty journey, and these distances above the floors should be equal to each other and the same as the "low" stopping figures taken during the down full load levelling test, if the down levelling gear is set correctly.

Car and Counterweight Clearances. The bottom car clearance and the top counterweight clearance may be measured with the car level with the bottom landing. In taking these measurements it may be more convenient to station the car a couple of feet above the bottom landing so that entrance to the pit is made easier. Due allowance must, of course, be made for the distance the car rests above the landing. The top car and bottom counterweight clearances must be obtained with the car at the top landing.

Car and Landing Gates. The lift should not operate with any gate open. The car gate delay contact and the retiring lock release cam must be tested.

Controller. The operation of the contactors and interlocks should be examined, also any time lag contacts, and it should be ascertained whether all the requirements laid down in the specification have been met. The earthing arrangements must be tested and insulation tests taken on both motor and control circuits at 500 volts d.c. with all wiring in circuit in each case.

Acceleration and Retardation. It can be judged whether these are sufficiently smooth by riding in the car.

Terminal and Ultimate Limit Switches. Test by letting the movement of the car operate each terminal limit switch. Hold in the controller contacts and thus cause the car to operate the ultimate limit switch at each end of the travel. By taking measurements it will be possible to ascertain the top and bottom over-travels.

APPENDIX I

FACTORIES ACT, 1937: SECTIONS RELATING TO LIFTS

Section 22. Hoists and Lifts.

(1) Every hoist or lift shall be of good mechanical construction, sound material and adequate strength, and be properly maintained.

(2) Every hoist or lift shall be thoroughly examined by a competent person at least once in every period of six months, and a report of the result of every such examination in the prescribed form and containing the prescribed particulars shall be signed by the person making the examination and shall within fourteen days be entered in or attached to the general register.

(3) Every hoistway or liftway shall be efficiently protected by a substantial enclosure fitted with gates, being such an enclosure as to prevent, when the gates are shut, any person falling down the way or coming into contact with any moving part of the hoist or lift.

(4) Any such gate as aforesaid shall be fitted with efficient interlocking or other devices to secure that the gate cannot be opened except when the cage or platform is at the landing and that the cage or platform cannot be moved away from the landing until the gate is closed.

Provided that, in the case of a hoist or lift constructed or reconstructed before the passing of this Act which it is not reasonably practicable to fit with such devices as aforesaid, it shall be sufficient if the gate is provided with such arrangements as will secure the aforesaid objects so far as is reasonably practicable, and in any event is kept closed and fastened except when the cage or platform is at rest at the landing.

(5) Every hoist or lift and every such enclosure as aforesaid shall be so constructed as to prevent any part of any person or any goods carried in the hoist or lift being trapped between any part of the hoist or lift and any fixed structure or between the counterbalance weight and any other moving part of the hoist or lift.

(6) There shall be marked conspicuously on every hoist or lift the maximum working load which it can safely carry and no load greater than that load shall be carried on any hoist or lift.

(7) The following additional requirements shall apply to hoists and lifts used for carrying persons, whether together with goods or otherwise—

(*a*) efficient automatic devices shall be provided and maintained to prevent the cage or platform overruning;

(*b*) every cage shall on each side from which access is afforded to a landing, be fitted with a gate, and in connexion with every such gate efficient devices shall be provided to secure that, when persons or goods are in the cage, the cage cannot be raised or lowered unless the gate is closed, and will come to rest when the gate is opened: Provided that, in the case of a hoist or lift constructed or reconstructed before the passing of this Act in connexion with which it is not reasonably practicable to provide such devices as aforesaid, it shall be sufficient if such arrangements are provided as will secure the aforesaid objects so far as is reasonably practicable, and in any event the gate is kept closed and fastened except when the cage is at rest or empty; and

(*c*) in the case of a hoist or lift constructed or reconstructed after the passing of this Act, where the platform or cage is suspended by rope or chain, there shall be at least two ropes or chains separately connected with the platform or cage, each rope or chain and its attachments being capable of carrying the whole weight of the platform or cage and its maximum working load, and efficient devices shall be provided and maintained which will support the platform or cage with its maximum working load in the event of a breakage of the ropes or chains or any of their attachments.

(8) In the case of a continuous hoist or lift, subsections (3) to (7) inclusive of this section shall not apply and in the case of a hoist or lift not connected with mechanical power subsections (4) and (7) shall not apply, and, in both the aforesaid cases, in subsection (2) for the reference to six months there shall be substituted a reference to twelve months.

(9) For the purposes of this section, no lifting machine or

appliance shall be deemed to be a hoist or lift unless it has a platform or cage the direction of movement of which is restricted by a guide or guides.

(10) Every teagle opening or similar doorway used for hoisting or lowering goods or materials, whether by mechanical power or otherwise, shall be securely fenced, and shall be provided with a secure handhold on each side of the opening or doorway. The fencing shall be properly maintained and shall, except when the hoisting or lowering of goods or materials is being carried on at the opening or doorway, be kept in position.

(11) If it is shown to the satisfaction of the Secretary of State that it would be unreasonable in the special circumstances of the case to enforce any requirement of this section in respect of any class or description of hoist, lift, hoistway, liftway, or teagle opening or similar doorway, he may by order direct that such requirement shall not apply as respects that class or description.

Section 23. Chains, Ropes and Lifting Tackle.

(1) The following provisions shall be complied with as respects every chain, rope, or lifting tackle used for the purpose of raising or lowering persons, goods, or materials—

(*a*) no chain, rope, or lifting tackle shall be used unless it is of good construction, sound material, adequate strength, and free from patent defect;

(*b*) a table showing the safe working loads of every kind and size of chain, rope, or lifting tackle in use, and, in the case of a multiple sling, the safe working load at different angles of the legs, shall be posted in the store in which the chains, ropes, or lifting tackle are kept, and in prominent positions on the premises, and no chain, rope, or lifting tackle not shown in the table shall be used, so, however, that the foregoing provisions of this paragraph shall not apply in relation to any lifting tackle if the safe working load thereof or, in the case of a multiple sling, the safe working load at different angles of the legs, is plainly marked upon it;

(*c*) no chain, rope, or lifting tackle shall be used for any load exceeding the safe working load thereof as shown by the table aforesaid or marked upon it as aforesaid;

(*d*) All chains, ropes, and lifting tackle in use shall be thoroughly examined by a competent person at least once in every period of six months or at such greater intervals as the Secretary of State may prescribe;

(*e*) no chain, rope, or lifting tackle except a fibre rope or fibre rope sling, shall be taken into use in any factory for the first time in that factory unless it has been tested and thoroughly examined by a competent person and a certificate of such a test and examination specifying the safe working load and signed by the person making the test and examination has been obtained and is kept available for inspection;

(*f*) every chain and lifting tackle except a rope sling shall, unless of a class or description exempted by certificate of the chief inspector upon the ground that it is made of such material or so constructed that it cannot be subjected to heat treatment without risk of damage or that it has been subjected to some form of heat treatment (other than annealing) approved by him, be annealed at least once in every fourteen months, or, in the case of chains or slings of half-inch bar or smaller, or chains used in connexion with molten metal or molten slag, in every six months, so, however, that chains and lifting tackle not in regular use need be annealed only when necessary;

(*g*) a register containing the prescribed particulars shall be kept with respect to all such chains, ropes, or lifting tackle, except fibre rope slings.

(2) In this section the expression "lifting tackle" means chain slings, rope slings, rings, hooks, shackles, and swivels.

APPENDIX II*

BRITISH STANDARD SIZES OF WIRE ROPES OF ROUND STRAND AND SPECIAL STRAND CONSTRUCTIONS

Circumference (in.)		Approximate Diameter (in.)	Circumference (in.)		Approximate Diameter (in.)
Round Strand Construction	Special Strand Construction		Round Strand Construction	Special Strand Construction	
$\frac{1}{2}$	—	—	$3\frac{1}{8}$	$3\frac{1}{8}$	1
$\frac{5}{8}$	—	—	$\frac{1}{4}$	$\frac{1}{4}$	—
$\frac{3}{4}$	—	—	$\frac{3}{8}$	$\frac{3}{8}$	$1\frac{1}{16}$
$\frac{7}{8}$	—	—	$\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{8}$
1	—	$\frac{5}{16}$	—	$\frac{3}{4}$	—
$\frac{1}{8}$	—	$\frac{3}{8}$	—	$\frac{7}{8}$	$1\frac{1}{4}$
$\frac{1}{4}$	—	—	—	4	—
$\frac{3}{8}$	—	$\frac{7}{16}$	—	$\frac{1}{4}$	—
$\frac{1}{2}$	$1\frac{1}{2}$	—	—	$\frac{3}{8}$	$1\frac{3}{8}$
$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{2}$	—	$\frac{1}{2}$	—
$\frac{3}{4}$	$\frac{3}{4}$	$\frac{9}{16}$	—	$\frac{3}{4}$	$1\frac{1}{2}$
2	2	$\frac{5}{8}$	—	5	—
$\frac{1}{8}$	$\frac{1}{8}$	$\frac{11}{16}$	—	$\frac{1}{8}$	$1\frac{5}{8}$
$\frac{1}{4}$	$\frac{1}{4}$	—	—	$\frac{1}{4}$	—
$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{4}$	—	$\frac{1}{2}$	$1\frac{3}{4}$
$\frac{1}{2}$	$\frac{1}{2}$	$\frac{13}{16}$	—	$\frac{3}{4}$	—
$\frac{3}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	—	6	$1\frac{7}{8}$
3	3	$\frac{15}{16}$			

---

* Reproduced by permission from British Standard Specification No. 329, *Round Strand Steel Wire Ropes for Lifts and Hoists* and from British Standard Specification No. 621, *Wire Ropes of Special Construction for Engineering Purposes.* Copies of each specification may be obtained from the British Standards Institution, 28 Victoria Street, London, S.W.1, price 2s. 2d. each, post free.

APPENDIX III*

BREAKING LOADS OF ROUND STRAND ROPES

TABLE I

Breaking Loads of Mild Patent Steel Ropes
60–70 tons per in.^{2}

Circumference (in.)	6 × 12 and Fibre (Actual Tons)	6 × 19 and 6 × 19 Seale (Actual Tons)	6 × 24 and Fibre (Actual Tons)
$\frac{1}{2}$	0·3	0·5	0·4
$\frac{5}{8}$	0·5	0·8	0·7
$\frac{3}{4}$	0·8	1·3	1·2
$\frac{7}{8}$	1·1	1·6	1·4
1	1·4	2·1	1·9
$\frac{1}{8}$	1·7	2·5	2·5
$\frac{1}{4}$	2·2	3·2	3·1
$\frac{3}{8}$	2·5	3·8	3·7
$\frac{1}{2}$	3·2	4·6	4·3
$\frac{5}{8}$	3·8	5·6	5·0
$\frac{3}{4}$	4·3	6·2	5·8
2	5·8	8·5	7·9
$\frac{1}{8}$	6·4	9·3	8·8
$\frac{1}{4}$	7·3	10·7	9·8
$\frac{3}{8}$	8·2	12·0	10·8
$\frac{1}{2}$	8·9	13·1	12·5
$\frac{3}{4}$	—	15·7	14·8
3	—	19·8	17·4
$\frac{1}{8}$	—	21·0	18·8
$\frac{1}{4}$	—	23·0	21·0
$\frac{3}{8}$	—	25·0	22·4
$\frac{1}{2}$	—	27·2	24·0

---

* Reproduced by permission from British Standard Specification No. 329, *Round Strand Steel Wire Ropes for Lifts and Hoists*, copies of which may be obtained from the British Standards Institution, 28 Victoria Street, London, S.W.1, price 2s. 2d., post free.

TABLE II

BREAKING LOADS OF PATENT STEEL ROPES

70–80 tons per in.^{2}

Circumference (in.)	6 × 12 and Fibre (Actual Tons)	6 × 19 and 6 × 19 Seale (Actual Tons)	6 × 24 and Fibre (Actual Tons)
$\frac{1}{2}$	0·4	0·6	0·5
$\frac{5}{8}$	0·6	0·9	0·8
$\frac{3}{4}$	0·9	1·4	1·2
$\frac{7}{8}$	1·3	1·9	1·7
1	1·7	2·4	2·1
$\frac{1}{8}$	2·0	2·9	2·9
$\frac{1}{4}$	2·6	3·7	3·6
$\frac{3}{8}$	2·9	4·4	4·2
$\frac{1}{2}$	3·6	5·3	5·0
$\frac{5}{8}$	4·4	6·4	5·8
$\frac{3}{4}$	4·9	7·1	6·6
2	6·7	9·8	9·1
$\frac{1}{8}$	7·4	10·7	10·1
$\frac{1}{4}$	8·4	12·6	11·3
$\frac{3}{8}$	9·5	13·9	12·4
$\frac{1}{2}$	10·3	15·1	14·4
$\frac{3}{4}$	—	18·1	17·1
3	—	22·8	20·1
$\frac{1}{8}$	—	24·2	21·6
$\frac{1}{4}$	—	26·5	24·1
$\frac{3}{8}$	—	28·9	25·8
$\frac{1}{2}$	—	31·3	27·6

TABLE III

Breaking Loads of Best Patent Steel Ropes

80–90 tons per in.^{2}

Circumference (in.)	6 × 12 and Fibre (Actual Tons)	6 × 19 and 6 × 19 Seale (Actual Tons)	6 × 24 and Fibre (Actual Tons)
$\frac{1}{2}$	0·4	0·7	0·6
$\frac{5}{8}$	0·7	1·1	0·9
$\frac{3}{4}$	1·1	1·6	1·4
$\frac{7}{8}$	1·4	2·1	1·8
1	1·9	2·8	2·4
$\frac{1}{8}$	2·3	3·3	3·3
$\frac{1}{4}$	2·9	4·3	4·0
$\frac{3}{8}$	3·4	4·9	4·8
$\frac{1}{2}$	4·1	6·0	5·7
$\frac{5}{8}$	5·0	7·2	6·6
$\frac{3}{4}$	5·6	8·1	7·5
2	7·6	11·1	10·3
$\frac{1}{8}$	8·4	12·1	11·6
$\frac{1}{4}$	9·5	13·9	12·8
$\frac{3}{8}$	10·8	15·7	14·1
$\frac{1}{2}$	11·7	17·0	16·3
$\frac{3}{4}$	—	20·5	19·3
3	—	25·8	22·7
$\frac{1}{8}$	—	27·5	24·5
$\frac{1}{4}$	—	30·0	27·3
$\frac{3}{8}$	—	32·7	29·2
$\frac{1}{2}$	—	35·5	31·3

TABLE IV

Breaking Loads of Special Improved Patent Steel Ropes

90–100 tons per in.^{2}

Circumference (in.)	6 × 12 and Fibre (Actual Tons)	6 × 19 and 6 × 19 Seale (Actual Tons)	6 × 24 and Fibre (Actual Tons)
½	0·5	0·8	0·7
⅝	0·8	1·2	1·1
¾	1·2	1·7	1·5
⅞	1·6	2·3	2·1
1	2·1	3·0	2·7
⅛	2·5	3·7	3·0
¼	3·2	4·7	4·5
⅜	3·8	5·5	5·4
½	4·6	6·7	6·3
⅝	5·6	8·1	7·3
¾	6·3	9·1	8·4
2	8·5	12·4	11·5
⅛	9·3	13·6	12·8
¼	10·7	15·6	14·3
⅜	12·0	17·6	15·8
½	13·0	19·8	18·2
¾	—	22·9	21·6
3	—	28·9	25·4
⅛	—	30·7	27·4
¼	—	33·6	30·5
⅜	—	36·6	32·7
½	—	39·6	35·0

TABLE V

Breaking Loads of Best Plough Steel Ropes

100–110 tons per in.^{2}

Circumference (in.)	6 × 12 and Fibre (Actual Tons)	6 × 19 and 6 × 19 Seale (Actual Tons)	6 × 24 and Fibre (Actual Tons)
$\frac{1}{2}$	0·6	0·9	0·8
$\frac{5}{8}$	0·9	1·3	1·2
$\frac{3}{4}$	1·3	1·9	1·7
$\frac{7}{8}$	1·8	2·6	2·3
1	2·3	3·4	3·0
$\frac{1}{8}$	2·8	4·1	4·1
$\frac{1}{4}$	3·6	5·2	5·0
$\frac{3}{8}$	4·1	6·1	5·9
$\frac{1}{2}$	5·1	7·4	7·0
$\frac{5}{8}$	6·2	9·0	8·1
$\frac{3}{4}$	6·9	10·0	9·3
2	9·4	13·7	12·7
$\frac{1}{8}$	10·3	15·0	14·2
$\frac{1}{4}$	11·8	17·2	15·8
$\frac{3}{8}$	13·3	19·4	17·4
$\frac{1}{2}$	14·4	21·1	20·1
$\frac{3}{4}$	—	25·3	23·9
3	—	31·9	28·1
$\frac{1}{8}$	—	33·9	30·3
$\frac{1}{4}$	—	37·1	33·8
$\frac{3}{8}$	—	40·4	36·1
$\frac{1}{2}$	—	43·8	38·7

TABLE VI

BREAKING LOADS OF SPECIAL IMPROVED PLOUGH STEEL ROPES
110–120 tons per in.^{2}

Circumference (in.)	6 × 12 and Fibre (Actual Tons)	6 × 19 and 6 × 19 Seale (Actual Tons)	6 × 24 and Fibre (Actual Tons)
½	0·6	0·9	0·8
⅝	1·0	1·4	1·3
¾	1·4	2·1	1·8
⅞	2·0	2·9	2·5
1	2·6	3·7	3·3
⅛	3·1	4·4	4·5
¼	3·9	5·8	5·5
⅜	4·6	6·6	6·5
½	5·6	8·2	7·7
⅝	6·7	9·9	8·9
¾	7·6	11·0	10·2
2	10·3	15·0	13·9
⅛	11·3	16·5	15·6
¼	12·9	18·8	17·3
⅜	14·6	21·3	19·1
½	15·8	23·1	22·0
¾	—	27·7	26·2
3	—	34·9	30·8
⅛	—	37·2	33·2
¼	—	40·6	36·9
⅜	—	44·3	39·6
½	—	48·0	42·3

APPENDIX IV*

BREAKING LOADS OF SPECIAL STRAND ROPES

TABLE I

BREAKING LOADS OF BEST PATENT STEEL ROPES
80–90 tons per in.^{2}

Circumference (in.)	5 × 27, 28, 29 Oval (Actual Tons)	6 × 25 Flattened Strand (Actual Tons)
1½	5·8	7·4
⅝	6·8	8·8
¾	8·0	10·0
2	10·7	13·1
⅛	12·1	14·9
¼	13·8	16·6
⅜	14·5	18·6
½	16·2	20·7
¾	19·9	25·1
3	24·1	29·5
⅛	26·2	32·0
¼	27·4	34·8
⅜	29·7	37·5
½	32·2	40·7
¾	37·3	46·6
⅞	40·0	49·9
4	42·8	52·8
¼	48·7	59·2
⅜	50·2	63·4
½	53·4	66·1
¾	60·0	73·5
5	—	81·4
⅛	—	—
¼	—	90·2
½	—	98·8
¾	—	107·2
6	—	116·7

---

* Reproduced by permission from British Standard Specification No. 621, *Wire Ropes of Special Construction for Engineering Purposes*, copies of which may be obtained from the British Standards Institution, 28 Victoria Street, London, S.W.1, price 2s. 2d., post free.

TABLE II

Breaking Loads of Special Improved Patent Steel Ropes

90–100 tons per in.^{2}

Circumference (in.)	5 × 27, 28, 29 Oval (Actual Tons)	6 × 25 Flattened Strand (Actual Tons)
1½	6·4	8·3
⅝	7·7	9·7
¾	9·0	11·0
2	11·9	14·6
⅛	13·6	16·4
¼	15·3	18·5
⅜	16·2	20·4
½	18·1	23·0
¾	22·3	27·8
3	26·9	32·7
⅛	29·4	35·7
¼	30·6	38·7
⅜	33·2	41·7
½	36·0	45·1
¾	41·7	51·8
⅞	44·7	54·8
4	47·8	58·4
¼	54·4	65·4
⅜	56·2	70·3
½	59·6	73·3
¾	67·0	81·1
5	—	90·1
⅛	—	—
¼	—	99·6
½	—	109·2
¾	—	118·6
6	—	130·8

TABLE III

Breaking Loads of Best Plough Steel Ropes

100–110 tons per in.^{2}

Circumference (in.)	5 × 27, 28, 29 Oval (Actual Tons)	6 × 25 Flattened Strand (Actual Tons)
1½	7·1	9·0
⅝	8·4	10·6
¾	9·9	12·1
2	13·2	15·9
⅛	15·0	17·7
¼	17·0	20·1
⅜	18·0	21·8
½	20·1	25·1
¾	24·7	30·5
3	29·8	35·7
⅛	32·4	38·9
¼	33·8	42·1
⅜	36·7	45·3
½	39·7	49·1
¾	46·0	56·4
⅞	49·4	60·4
4	52·9	63·9
¼	60·1	71·6
⅜	62·0	78·5
½	65·9	79·5
¾	74·1	89·5
5	—	99·0
⅛	—	—
¼	—	109·9
½	—	120·9
¾	—	130·9
6	—	142·5

TABLE IV

BREAKING LOADS OF SPECIAL IMPROVED PLOUGH STEEL ROPES
110–120 tons per in.^{2}

Circumference (in.)	5 × 27, 28, 29 Oval (Actual Tons)	6 × 25 Flattened Strand (Actual Tons)
1½	7·7	9·8
⅝	9·2	11·5
¾	10·9	13·2
2	14·4	17·1
⅛	16·5	19·2
¼	18·6	21·8
⅜	19·7	24·3
½	22·0	27·1
¾	27·0	32·8
3	32·6	38·6
⅛	35·5	42·0
¼	37·0	45·8
⅜	40·2	49·2
½	43·5	53·7
¾	50·5	61·0
⅞	54·1	65·5
4	57·9	69·3
¼	65·9	77·6
⅜	68·0	84·3
½	72·3	86·2
¾	81·1	97·2
5	—	107·7
⅛	—	—
¼	—	119·5
½	—	130·8
¾	—	142·0
6	—	154·3

APPENDIX V

INTERFERENCE WITH WIRELESS RECEPTION DUE TO ELECTRIC LIFTS

Sources of Interference. The items of lift equipment which may cause interference with wireless reception consist of the driving motor, which gives a continuous noise in the receiver, and the controller, giving noises of the "click" type. The radiated interference is further increased because the interfering sources are connected to the car flexible cable and to the wiring between gate interlocks and the controller and the supply mains. The latter wiring is frequently in steel conduit, but the flexible cable normally has no metallic protection. Interference may thus reach the wireless receiver by way of the electric mains or by direct radiation from the motor and controller, from wiring in the well, or from the flexible cable acting as a radiating aerial. In addition, the metal enclosure of the well is frequently inadequately earthed, and this gives rise to voltages along the well which may cause serious interference.

The radiated motor interference is less than that due to the control circuits if the motor is properly maintained, the motor noise being negligible if a motor generator set is employed, whilst even for d.c. motors with direct mains supply the noise is generally less than the controller noise except where the motors are not efficiently maintained. Auxiliary motors such as brake or door opening motors are also possible sources of interference.

Controller interference is mainly due to the circuits controlling the driving motor contactor coils and the brake coil, these being most troublesome when supplied direct from the mains. All circuits for remote control, particularly those entering the flexible cable, form systems which give a high frequency radiation, whilst the brake magnet is also a radiating source. A.c. controllers usually cause very little disturbance.

The interference from the sources mentioned above appears also as interfering voltages at the supply terminals, thus causing mains-borne interference.

Methods of Suppression. Two methods are employed to prevent interference at the source—

(*a*) By preventing the generation of the interference.

(*b*) By limiting the effect of the interference and preventing its radiation or its passage to the power supply mains.

The first method can often be adopted on the controller switches by incorporating spark quenching circuits, but in the majority of cases it is necessary to prevent the interference from leaving the source. This is done by screening as far as radiation is concerned, and by the use of filter circuits to prevent the passage of the disturbing radio-frequency currents to the supply mains.

Lift Motors. Most interference is caused by commutator machines and is usually worse if sparking is present at the commutators. In the case of the smaller d.c. motors, condensers alone often give adequate suppression. Two condensers (either 2 μF. or 4 μF.) joined in series across the supply mains are usually sufficient. The centre point of the condensers must be connected to the frame of the machine which should be efficiently earthed. A greater degree of suppression is often obtained, however, when the condensers are connected directly to the brushgear with the leads as short as possible. For the larger d.c. machines two radio frequency chokes may be necessary in addition to condensers. The chokes should be about 600 μH., connected one in each main lead to the motor, either on the mains or motor side of the condensers. If the motor impedance is low and the mains impedance high the chokes should be fitted on the motor side of the condensers and vice versa.

A.c. motors, with the exception of commutator motors, do not usually cause as much interference as d.c. motors. Suppression in the case of a.c. commutator motors is effected by a choke condenser filter similar to that described for d.c. motors. The single-phase repulsion-induction motor is an interfering type, however, and since the armature is normally short-circuited, the fitting of condensers across the brushes cannot effect a cure. It is therefore necessary to insert condensers and chokes in the mains leads as for d.c. motors. Induction motors of both the squirrel-cage and slip-ring types do not usually give trouble if they are properly maintained.

Control Circuits, etc. The radiated interference due to the control circuits entering the car flexible cable may be suppressed by chokes of about 6 mH. connected in each lead of the flexible cable both at the car and the controller ends. In addition, condensers of 0·5 μF. or 1 μF. may be connected from each lead to earth on the flexible cable side of the chokes. Suppression may sometimes be obtained by mounting the chokes at the half-way box in the well instead of in the car, whilst the chokes at the controller end may often be omitted. The former method is generally necessary when the control circuits are energized from the full mains voltage.

Control circuits such as gate interlocks which do not enter the flexible cable are treated in a similar manner, filters being required at the operating switch and the relay coil. If the wiring is in conduit or screened, the chokes may often be omitted from the filters.

The coils of the circuit-breaker and controller contacts should be fitted with condensers of 1 μF. or 2 μF. capacitance connected between each end of the coil and earth. It is often advantageous to connect condensers up to 4 μF. across the car switch contacts. Interference due to the brake magnet coil can be suppressed by an arc suppressor of the rectifier type. The metal work of the well should be efficiently earthed.

Any interference passing into the mains supply can be reduced by a choke condenser filter in the mains.

BIBLIOGRAPHY

A. S. Angwin: Institution of Post Office Electrical Engineers printed paper No. 137.

A. J. Gill and S. Whitehead: "Electrical Interference with Radio Reception." (*I.E.E. Journal*, Vol. 83, p. 345.)

A. Morris: "Interference of Electrical Plant with the reception of Radio Broadcasting." (*I.E.E. Journal*, Vol. 74, p. 245.)

INDEX

INDEX

ACCELERATION, rate of, 8, 33
Albert lay, 42
Automatic control, 5, 10, 11, 84, 187, 202, 207, 236, 239, 245

BALANCE, lift, 262
Bank of lifts, 6
Bed lifts, 13
Booster, variable voltage, 85, 230
Brakes, a.c. and d.c., 92
——, eddy-current, 68
——, electromagnetic, 90
——, hand release, 92, 221
——, maintenance of, 251
——, noises, 23
——, oil immersed, 93
——, operation of, 92
——, torque motor, 95, 97
Braking, dynamic, 59, 61, 71, 79, 92
Buffers, oil, 3, 181, 184
——, spring, 3, 181
Bulldog clips, 51

CAM, retiring lock release, 24, 142, 150, 248, 258
—— type safety gear, 3, 163, 169, 259
Capacitor motors, 79
Car, all-metal, 112, 114
—— clearances, 176, 262
—— construction, 3, 111, 112
—— emergency exits, 107
—— —— handle, 104, 184, 261
—— flexible cable, 114
—— floor, 110
—— —— switch, 110, 258
—— gate delayed contact, 145, 219, 249
——, goods, 113
—— height, 107
—— indicators, 154
—— intercommunication system, 157
——, passenger, 107

Car, size and capacity, 5, 259
—— sling, 107
—— stop button, 235
—— terminal box, 111, 114
Change-over switch, 221, 236, 239, 245
Clearances, car and counterweight, 176, 262
——, controller, 20, 213
Coefficient of friction, 32, 33
Collective control, 5, 202, 208, 211
Commutator motors, a.c. polyphase, 71, 239
—— ——, —— single-phase, 80
Compensating ropes, 41
Control, automatic, 5, 10, 11, 84, 187, 202, 207, 236, 239, 245
——, car switch, 5, 84, 187, 202, 222, 230
——, collective, 5, 202, 208, 211
——, departmental stores, 202, 205
——, dual, 5, 202, 211
——, —— voltage, 216
—— features, 4, 219
—— interlocks, 4, 220, 221, 249, 251
—— panel, 213
——, pre-register, 202, 203
—— rectifiers, 153, 216, 218
——, semi-automatic, 10, 11, 202, 208, 237
——, signal, 202, 206
——, slip-ring variable voltage, 66, 218
—— systems, 202
——, variable voltage, 62, 83, 189, 230
Controller clearances, 20, 213
—— contacts, 214, 254
——, enclosed, 24
——, maintenance of, 253
—— wiring diagrams, 222, 226, 230, 236, 237, 239, 245, 259
Counterweight clearances, 176, 262
——, construction of, 4, 116
—— guards, 16, 17, 123
——, independent, 39, 41
——, machine, 39, 41
Counters, controller, 221
Costs, lift, 5
Cross-over drive, 37

DEAD-LOAD test, 260
Demagnetizing windings, 87

Departmental stores control, 202, 205
Direction switches, 190, 236, 237
—— ——, adjustment of, 255
Directional collective control, 211
Dispatching of cars, 211
Diverter resistance, 59, 61
Doors, advantages of, 126
——, automatic, 141
——, centre opening, 132, 137
——, designs for, 137, 139
——, interlocks for, 144, 147, 150, 227
——, methods of operation, 139
——, "Peelle" type, 131
——, power operated, 141, 230
——, self-closing, 141
——, steel shutter, 131
——, two-speed sliding, 132, 136, 137
Drive, cross-over, 37
——, double-wrap, 32, 37, 39
——, drum, 34, 41
——, full-wrap, 37
——, half-wrap, 37
——, single-wrap, 31, 37
——, traction, 26, 37
Drum diameter, 28, 35
—— grooves, 35
Dual control, 5, 202, 211
—— voltage control, 216
Dynamic braking, 59, 61, 71, 79, 92

EDDY-CURRENT brake, 68
Efficiency of gearing, 103
Energy consumption, 260
Equalizing gear, rope, 55
Exciter, variable voltage, 83, 85, 230

FACTOR of safety, rope, 2, 45
Factories Act, 1937, 265
Final limit switch, 180
Flattened strand ropes, 47, 48, 276
Flexible cable, car, 114
Floor relays, 236, 237, 245
—— selector, 190, 234
—— ——, adjustment of, 254

Floor switch, car, 110, 258
Friction, coefficient of, 32, 33
Full-wrap drive, 37
Fuses, 250

GATES, collapsible, 3, 126
——, delayed contact, 145, 219, 249
——, hollow tube, 126
——, interlocks, 144, 147, 150, 227
——, locks, 144, 146
——, methods of operation, 139
——, mid-bar, 3, 126
——, noise, 25
——, "Nu-bar," 3, 126
Gearing, efficiency of, 103
——, irreversible, 102, 186, 261
——, maintenance of, 252
—— noise, 24
——, over-and-under types, 100
——, spur, 106
——, tandem, 105
——, worm, 3, 99, 102
Gearless motor, 37, 41, 61, 62, 74, 82, 95, 230
Goods cars, 113
—— lift, 1, 9, 10, 13
Governor, maintenance of, 256
——, overspeed, 167, 169, 172
—— rope carriers, 170
—— tripping speeds, 172
Grooves, drum, 35
——, pulley, 33, 38
——, sheave, 3, 28, 29, 37, 38
Guards, counterweight, 16, 17, 123
——, well, 16
Guides, backings for, 121, 165
——, clamps for, 121
—— details of, 3, 117
——, fixing and jointing of, 118
——, lubrication of, 259
——, shoes for, 110, 116
——, steel, 3, 117, 121, 123

HALF-WRAP drive, 37

INDEPENDENT counterweight, 39, 41
Indicators, car, 154
——, directional, 159
——, landing, 158
——, position, 159, 161
——, target, 155
——, wiring of, 155, 160
Inducer levelling system, 200
Induction motors. (See Motors)
Inductor levelling system, 200
Installations, lift, 12, 13
Interceptive collective control, 211
Intercommunication between cars, 157
Interlocks, control, 4, 220, 221, 249, 251
——, door or gate, 144, 147, 150, 227

LANDING indicators, 158
Lang's lay, 42
Lay, rope, 42, 43, 45
"Leveltric" levelling system, 196
Levelling, corrective, 10, 192, 234, 239
——, straight-to-floor, 226, 230
—— switch, 234, 239, 242, 244
—— systems, 187
——, testing of, 261, 262
Lift installations, 12, 13
Lifting joists, 22
Limit switches, 177, 180, 226, 239
Loads on overhead structure, 15, 21, 36
Locks, door or gate, 144, 146
——, requirements of, 150
——, wiring of, 152

MACHINE counterweight, 39, 41
—— room, area of, 20
—— ——, height of, 4, 19
—— ——, location of, 17, 36
—— ——, ventilation of, 18, 19
Maintenance, 250
Micro-drive, 193
Mid-bar gates, 3, 126
Motors, a.c. commutator polyphase, 71, 239
——, —— ——, single-phase, 80
——, capacitor, 79

Motors, compound, 58
——, cost of, 74
——, details of, 56
——, d.c., acceleration of, 59
——, ——, single-speed, 57
——, ——, two-speed, 60
——, gearless, 37, 41, 61, 62, 74, 82, 95, 230
——, h.p. of, 56
——, induction, 62, 63, 65
——, maintenance of, 251
——, noise, 23
——, repulsion-induction, 74
——, tandem, 69, 245
Multiple slowing switch, 179, 235

NOISE, lift, 22
Non-interruption relay, 244
"Nu-bar" gates, 3, 126

OIL buffers, 3, 181, 184
One-to-one roping system, 37
Ordinary lay, 42
Overtravels, top and bottom, 177, 263

PASSENGER lifts, 1, 12
"Patenting," 42
Peak periods, 7
"Peelle" type doors, 131
Pit, 14
Preformed ropes, 48
—— ——, advantages of, 50
Pre-register control, 202
Pulleys, construction of, 2, 26, 28
——, diameter of, 28, 34
——, diverting, 33, 34
——, grooves for, 33, 38
——, maintenance of, 253

QUALITY of service, 7, 8

RECORDS, lift working, 221
Rectifiers, 79, 153, 216, 218
Regular lay, 42
Relay, floor, 236, 237, 245

Relay, non-interruption, 244
——, reverse phase, 220
Retardation, rate of, 8
Retiring lock release cam, 24, 142, 150, 248, 258
Repulsion-induction motors, 74
Ropes, breaking loads of, 270, 276
——, bulldog clips for, 51
——, constructions of, 45, 47
——, compensating, 41
——, cores of, 46
——, equalizing gear for, 55
——, factor of safety, 2, 45
——, fastenings for, 50
——, flattened strand, 47, 48, 276
——, lay of, 42
——, lubricants for, 33, 46
——, maintenance of, 256
——, material for, 41
——, minimum number, 38
——, non-standard, 46
——, preformed, 48
    -, advantages of, 50
——, renewal of, 257
——, round strand, 45, 269
——, Seale construction, 46
——, size of, 42, 269
——, sockets for, 53
——, specification for, 2
——, spliced ends, 51
——, tensile strength of, 42, 45, 47
——, Warrington construction, 47
Roping systems, 36
Round trip time, 6, 8

SAFETY GEAR, cam type, 3, 163, 169, 259
—— ——, flexible guide clamp, 3, 174
—— ——, gradual wedge clamp, 3, 167
—— —— stopping distances, 175
—— ——, testing of, 259, 261
Seale rope, 46
Service lifts, 1, 10, 11, 13, 150
——, quality of, 7, 8
Sheaves, construction of, 2, 26, 28
——, diameter of, 27, 28

Sheaves, grooves for, 3, 28, 29, 37, 38
——, maintenance of, 253
Shoes, guide, 110, 116
Signal control, 202, 206
Single-wrap drive, 31, 37
Sling, car, 107
Slip-ring variable voltage control, 66, 218
Sockets, rope, 53
Specification, lift, 2
Speeds, maximum, 4, 8
——, testing of, 261
——, typical lift, 12, 13
Splices, rope, 51
Spur gearing, 106
Stops per journey, 8
Switches, main, 250

TANDEM gearing, 105
—— motors, 69, 245
Target indicators, 155
Tee-section guides, 3, 117, 121, 123
Terminal limit switch, 3, 177, 226, 239, 263
Tests, acceptance, 259
Test buttons, 236, 239, 245, 248
Thrust races, 105, 253
Torque motor brakes, 95, 97
Traction drive, 26, 37
Two-to-one roping system, 39

U-GROOVE, 29, 37
Ultimate limit switch, 3, 180, 249
—— —— ——, testing of, 255, 263

VARIABLE voltage booster, 85, 230
—— —— control, 62, 83, 189, 230
—— —— ——, slip-ring, 66, 218
—— —— exciter, 85, 230
—— —— set, speed regulation of, 84
Vee-groove. (See Grooves)
Ventilation of machine room, 18, 19
Vibration, 24

WAITING intervals, 8
Ward-Leonard control, 62, 83

Warrington rope, 47
Well, details of, 14, 16
——, double-walled, 24
—— guarding, 16
—— terminal box, 116
Wireless interference, 280
Wiring diagrams, controller, 222, 226, 230, 236, 237, 239, 245, 259
Wiring, electrical, 3
—— of indicators, 155, 160
—— of locks, 152
Worm gearing, 3, 99, 102

MADE IN GREAT BRITAIN AT THE PITMAN PRESS BATH
C8—(T.116

FOR EVERY KIND OF LIFT

CONSULT

E-C-M

MAKERS OF ALL KINDS
OF LIFTS
FOR ALL PURPOSES

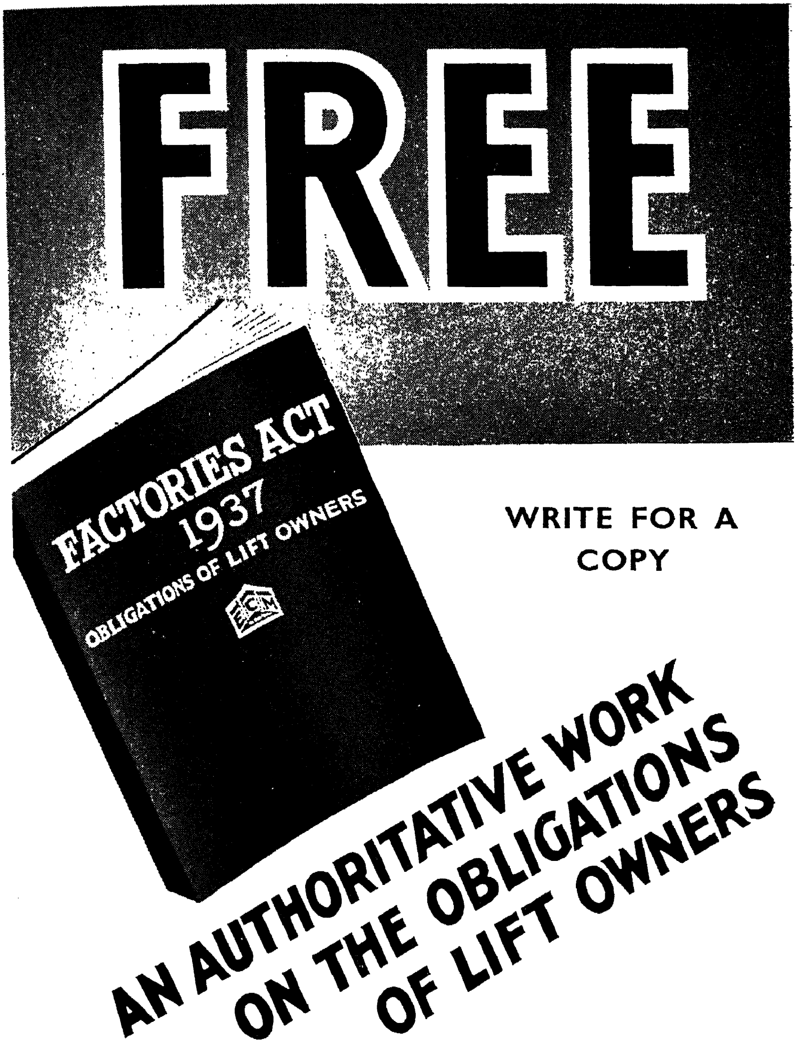
ETCHELLS, CONGDON & MUIR LTD.

are continually planning, manufacturing and supplying for home and abroad

PASSENGER LIFTS
GOODS LIFTS
SERVICE LIFTS
HOSPITAL LIFTS
etc., etc.

ETCHELLS, CONGDON & MUIR, LTD.
ANCOATS · MANCHESTER 4.

London Office: 25 Victoria Street, S.W.1
Branches at Birmingham, Liverpool, Edinburgh and Sheffield



FREE

WRITE FOR A
COPY

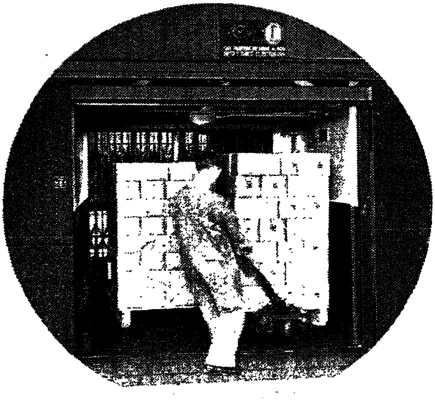
AN AUTHORITATIVE WORK
ON THE OBLIGATIONS
OF LIFT OWNERS

ETCHELLS, CONGDON & MUIR, LTD.
ANCOATS · MANCHESTER 4.

London Office: 25 Victoria Street, S.W.1
Branches at Birmingham, Liverpool, Edinburgh and Sheffield

WADSWORTH LIFTS

SUPPLY THE ANSWER TO EVERY VERTICAL TRANSPORT PROBLEM



Above illustration shows lifts of the modern high-speed type; the method of control is known as the Ward-Leonard Variable-voltage Control (Wadsworth Patent), and each lift is fitted with automatic centre-opening landing gates, "straight-to-floor" levelling gear, illuminated indicators, indirect lighting, etc. etc.

On the left is shown a typical Wadsworth Goods lift.
Its capacity is 5 tons, it has variable-speed car switch control, is also equipped with "straight-to-floor" levelling, and has automatic power-operated gates.

WADSWORTH
Electric LIFTS

WM. WADSWORTH & SONS, LTD.
HIGH STREET, BOLTON, LANCS.
London Office: 72-74 VICTORIA STREET, WESTMINSTER, S.W.1
Also at:
Manchester, Birmingham, Newcastle-on-Tyne, Liverpool, Glasgow, Dublin, Bristol

● **SILENT OPERATION**

—because of high grade materials

● **MAINTAINED EFFICIENCY**

—due to high quality craftsmanship

● **TECHNICALLY** advanced design

—because of the expert knowledge of requirements . . and

● **COMPETITIVELY PRICED**

—because the component parts are mass produced

WRITE FOR DATA ON **BOLTON COLLAPSIBLE GATES FOR LIFTS:** Made in both Shutter type and Mid Bar type. Ask for details of Gates which can be finished to match any timber surface or other surround to harmonise with the architectural scheme.

BOLTON *Collapsible* (PATENTED) **GATES**

WATERLOO STREET, BOLTON, LANCS.

Also at LONDON, BIRMINGHAM, MANCHESTER, GLASGOW, BELFAST, ETC.

BG.123

SHAW
LIFTS
for all
PURPOSES

R. J. SHAW & CO., LTD.
Manufacturers of all Types of Lift and Hoist Equipment
ABBOTS ROAD WORKS
GATESHEAD-ON-TYNE Telephone 71796

An Abridged List of

TECHNICAL BOOKS

published by

Sir Isaac Pitman & Sons, Ltd.

A complete Catalogue of Technical and Scientific Books will be sent post free on request

*All prices are net, except those marked **

TEXTILE MANUFACTURE, ETC.

	s.	*d.*
Cotton Spinner's Pocket Book, The. By J. F. Innes. 3rd Ed.	3	6
*Cotton Spinning Course, A First Year. By H. A. J. Duncan, A.T.I.	3	6
Jute Spinning Calculations. By Andrew Smith	5	0
Pattern Construction, The Science of. For Garment Makers. By B. W. Poole, M.R.S.T. Second Edition.	45	0
Tailoring, Practical. By J. E. Liberty, U.K.A.F.	7	6
Tailoring, Simplified, Ladies. By M. E. D. Galbraith	7	6
*Textiles, Introduction to. By A. E. Lewis, A.M.C.T.	3	6
Worsted Carding and Combing. By J. R. Hind, M.R.S.T.	7	6
Worsted Open Drawing. By S. Kershaw, F.T.I.	5	0
Yarns and Fabrics, The Testing of. By H. P. Curtis, P.T.I. Second Edition	5	0

DRAUGHTSMANSHIP

	s.	*d.*
Applied Perspective. By John Holmes, F.R.S.A.	6	6
*Engineering Drawing, A First Year. By A. C. Parkinson, A.C.P. (Hons.), F.Coll.H. Second Edition	5	0
Engineering Drawing, Intermediate. By A. C. Parkinson, A.C.P. (Hons.), F.Coll.H. Second Edition	7	6
*Engineering Workshop Drawing. By A. C. Parkinson, A.C.P. (Hons.), F.Coll.H. Fourth Edition	4	0
*Foundations of Technical Drawing. By A. C. Parkinson, A.C.P. (Hons.), F.Coll.H.	2	6
Plan Copying Processes and Equipment Modern. By B. J. Hall, M.I.Mech.E., and B. Fairfax Hall, M.A.	5	0
Limp cloth edition	4	0

CHEMISTRY, PHARMACY, ETC.

	s.	d.
DISPENSING FOR PHARMACEUTICAL STUDENTS. By J. W. Cooper, Ph.C., and F. J. Dyer. Sixth Edition, Revised and re-written by J. W. Cooper	8	6
*LATIN FOR PHARMACEUTICAL STUDENTS. By J. W. Cooper and A. C. McLaren. Third Edition	6	0
PHARMACEUTICAL CHEMISTRY, PRACTICAL. By F. N. Appleyard, B.Sc. (Lond.), F.I.C., Ph.C., and C. G. Lyons. Third Edition	6	6
PHARMACEUTICAL CHEMISTRY, THEORETICAL. By C. G. Lyons, M.A., Ph.D. (Cantab.)	12	6
PHARMACOGNOSY, TEXTBOOK OF. By J. W. Cooper, Ph.C., and T. C. Denston, B.Pharm., Ph.C. With illustrations and drawing notes by M. Riley, A.T.D., and D. W. Shaw, B.Sc., Ph.C. Second Edition	18	0
TUTORIAL PHARMACY. By J. W. Cooper, Ph.C. Third Edition	17	6
VOLUMETRIC ANALYSIS. By J. B. M. Coppock, Ph.D., B.Sc., A.I.C., and J. B. Coppock, B.Sc. (Lond.), F.I.C., F.C.S. Third Edition	3	6

PLASTICS

ARTIFICIAL RESINS. By J. Scheiber, Ph.D., and Kurt Sändig. Translated by Ernest Fyleman, B.Sc., Ph.D., F.I.C.	15	0
CELLULOSE LACQUERS, THE. By S. Smith, O.B.E.	7	6
PROCESSES AND MACHINERY IN THE PLASTICS INDUSTRY. By Kurt Brandenburger. Translated by H. I. Lewenz, M.I.Mech.E.	25	0

METALLURGY, FOUNDRYWORK, ETC.

ALUMINIUM AND ITS ALLOYS. By N. F. Budgen, Ph.D., M.Sc.	15	0
ELECTROPLATING. By S. Field, A.R.C.Sc., and A. Dudley Weill. Third Edition	12	6
ENGINEERING MATERIALS. By A. W. Judge, Wh.Sc., A.R.C.S. In three volumes—Vol. I, FERROUS, 30s.; Vol. II, NON-FERROUS, 40s.; Vol. III, THEORY AND TESTING OF MATERIALS, 21s.		
METAL WORK, PRACTICAL SHEET AND PLATE. By E. A. Atkins, M.Sc., M.I.Mech.E., M.I.W. Fourth Edition	7	6
METALLURGY OF BRONZE. By H. C. Dews	12	6
METALLURGY OF CAST IRON. By J. E. Hurst	15	0
METALS AND ALLOYS, THE MECHANICAL TESTING OF. By P. Field Foster, B.Sc., M.Sc., A.M.I.Mech.E.	15	0
PANEL BEATING AND SHEET METAL WORK. By Sidney Pinder	4	0
SPECIAL STEELS. Chiefly founded on the Researches regarding Alloy Steels of Sir Robert Hadfield, Bt., D.Sc., etc. Second Edition. By T. H. Burnham, B.Sc. Hons. (Lond.), A.M.I.Mech.E., M.I.Mar.E.	12	6
WELDING, ELECTRIC ARC AND OXY-ACETYLENE. By E. A. Atkins, M.I.Mech.E., etc. and A. G. Walker, M.Inst.W. Third Edition	8	6
WELDING, ELECTRIC, THE PRINCIPLES OF. By R. C. Stockton, A.I.M.M., A.M.C.Tech.	7	6

MINERALOGY AND MINING

For particulars of Pitman Books on the above subjects, send for separate list.

CIVIL ENGINEERING, BUILDING, ETC.

	s.	d.
Architectural Hygiene; or, Sanitary Science as Applied to Buildings. By Sir Bannister Fletcher, M.Arch. (Ireland), F.S.I., *Barrister-at-Law*, and Major H. Phillips Fletcher, D.S.O., F.R.I.B.A., F.S.I., etc. Sixth Edition	10	6
Architectural Practice and Administration By H. Ingham Ashworth, B.A., A.R.I.B.A.	12	6
Brickwork, Concrete, and Masonry. Edited by T. Corkhill, M.I.Struct.E. In eight volumes . *Each*	6	0
Building Encyclopaedia, A Concise. Compiled by T. Corkhill, M.I.Struct.E.	7	6
*Building Geometry. By Richard Greenhalgh, A.I.Struct.E.	4	6
Building, Mechanics of. By Arthur D. Turner, A.C.G.I., A.M.Inst.C.E.	5	0
Engineering Equipment of Buildings. By A. C. Pallot, B.Sc. (Eng.)	15	0
Fabric of Modern Buildings, The. By E. G. Warland, M.I.Struct.E.	20	0
Flats, Design and Equipment. By H. Ingram Ashworth, B.A., A.R.I.B.A.	25	0
Hydraulics. By E. H. Lewitt, B.Sc. (Lond.), A.M.I.M.E. Fifth Edition	10	6
Joinery and Carpentry. Edited by R. Greenhalgh, A.I.Struct.E. In six volumes . *Each*	6	0
Painting and Decorating. Edited by C. H. Eaton, F.I.B.D. In six volumes . *Each*	7	6
Plumbing and Gasfitting. Edited by Percy Manser, R.P., A.R.S.I. In seven volumes . *Each*	6	0
Plumbing Engineering. By Walter S. L. Cleverdon	12	6
Reinforced Concrete Arch Design. By G. P. Manning, M.Eng., A.M.Inst.C.E.	12	6
Structures, The Theory of. By H. W. Coultas. M.Sc. A.M.I.Struct.E., A.I.Mech.E. Second Edition	18	0
Surveying, Advanced. By Alex. H. Jameson, M.Sc., M.Inst.C.E.	12	6
Water Supply Problems and Developments. By W. H. Maxwell, A.M.Inst.C.E. Second Edition	25	0
Waterworks for Urban and Rural Districts. By H. C. Adams, M.Inst.C.E., M.I.M.E., F.R.S.I. Third Edition	15	0
Woodworking by Machinery. By Robert H. Hordern	4	0

MECHANICAL ENGINEERING

Condenser, The Surface. By B. W. Pendred, A.M.I.Mech.E.	8	6
Engineering Educator, Pitman's. Edited by W. J. Kearton, D.Eng., M.I.Mech.E., A.M.Inst.N.A. In three volumes. Second Edition	63	0

Mechanical Engineering—contd.

	s.	d.
*ENGINEERING, INTRODUCTION TO. By R. W. J. Pryer, B.Sc. (Eng.), A.M.I.Mech.E., A.M.I.A.E.	2	0
*ENGINEERING SCIENCE, EXPERIMENTAL. By Nelson Harwood, B.Sc., A.M.I.Mech.E.	7	6
ENGINEERING SCIENCE, MECHANICAL AND ELECTRICAL, FIRST YEAR. By G. W. Bird, Wh.Ex., A.M.I.Mech.E., etc. Revised by B. J. Tams, M.Sc.Tech., A.M.I.Mech.E. Second Edition	5	0
ENGINEERING SCIENCE, MECHANICAL, SECOND YEAR By G. W. Bird, Wh.Ex., B.Sc., A.M.I.Mech.E., etc.	5	0
HYDRAULICS. By E. H. Lewitt, B.Sc. Fifth Edition	10	6
HYDRAULICS FOR ENGINEERS. By R. W. Angus, B.A.Sc., M.E. Second Edition	12	6
HYDRO- AND AERO-DYNAMICS. By S. L. Green, M.Sc.	12	6
MACHINES PROBLEMS, EXAMPLES IN THEORY OF. By W. R. Crawford, M.Sc., Ph.D.	5	0
*MECHANICS FOR ENGINEERING STUDENTS. By G. W. Bird, B.Sc., A.M.I.Mech.E. Revised by G. W. T. Bird, B.Sc. Third Edition	5	0
STEAM TURBINE OPERATION. By W. J. Kearton, D.Eng., M.I.Mech.E., A.M.Inst.N.A. Third Edition	12	6
STEAM TURBINE THEORY AND PRACTICE. By W. J. Kearton, D.Eng., M.I.M.E., A.M.Inst.N.A. Third Edition	15	0
STRENGTH OF MATERIALS. By F. V. Warnock, Ph.D., M.Sc. (Lond.), F.R.C.Sc.I., A.M.I.Mech.E. Third Edition	10	6
SUPERHEATER IN MODERN POWER PLANT. By D. W. Rudorff, Dipl. Ing., A.Am.I.E.E., M.Inst.F.	21	0
THEORY OF MACHINES. By Louis Toft, M.Sc.Tech., and A. T. J. Kersey, A.R.C.Sc. Third Edition	12	6
THERMODYNAMICS, APPLIED. By William Robinson, M.E., M.Inst.C.E., M.I.Mech.E. Revised by John M. Dickson. B.Sc. Second Edition	18	0
THERMODYNAMICS APPLIED TO HEAT ENGINES. By E. H. Lewitt, B.Sc., A.M.I.Mech.E. Second Edition	12	6
THERMODYNAMICS PROBLEMS, EXAMPLES IN. By W. R. Crawford, M.Sc., Ph.D.	5	0
THERMODYNAMICS, TECHNICAL By Professor Dipl.-Ing. W. Schüle. Translated from the German by E. W. Geyer, B.Sc.	40	0
WORKSHOP PRACTICE. Edited by E. A. Atkins, M.I.Mech.E., M.I.W.E. In eight volumes . . . . . *Each*	6	0

AERONAUTICAL

Write for separate list of over 60 books on aeronautics and aeronautical engineering.

MOTOR ENGINEERING, ETC.

Write for the complete list of motoring books, containing over 50 titles.

OPTICS AND PHOTOGRAPHY

Applied Optics, Introduction to. By L. C. Martin, D.Sc., A.R.C.S., D.I.C. Vol. I. General and Physiological. Vol. II. Theory and Construction of Instruments. In two volumes. . . . . Each	21	0
Camera in Commerce, The. By David Charles, F.R.P.S. . .	10	6
Camera Lenses. By A. W. Lockett. Revised by H. W. Lee. Second Edition	2	6
Colour Photography in Practice. By D. A. Spencer, Ph.D., F.I.C., F.R.P.S.	21	0
Colour Sensitive Materials. By Robert M. Fanstone, A.R.P.S.	8	6
Photographic Chemicals and Chemistry. By J. Southworth and T. L. J. Bentley, D.I.C., A.R.C.Sc., B.Sc.	3	6
Photography Theory and Practice. By L. P. Clerc. Edited by the late G. E. Brown, F.I.C., etc. Second Edition .	35	0
Retouching and Finishing for Photographers. By J. S. Adamson. Third Edition	4	0
Studio Portrait Lighting By H. Lambert, F.R.P.S. Second Edition	15	0

ELECTRICAL ENGINEERING, ETC.

Accumulator Charging, Maintenance, and Repair. By W. S. Ibbetson. Sixth Edition	4	6
Alternating Current Bridge Methods. By B. Hague, D.Sc. Fourth Edition	25	0
Alternating Current Circuit. By Philip Kemp M.Sc., M.I.E.E., Mem.A.I.E.E. Second Edition	2	6
Alternating Current Machines, Performance and Design of. By M. G. Say, Ph.D., M.Sc., A.C.G.I., D.I.C., A.M.I.E.E., F.R.S.E., and E. N. Pink, B.Sc., A.M.I.E.E.	20	0
Alternating Current Work. By W. Perren Maycock, M.I.E.E. Second Edition	7	6
Alternating Currents, The Theory and Practice of. By A. T. Dover, M.I.E.E. Second Edition	18	0
Automatic Protective Gear for A.C. Supply Systems. By J. Henderson, M.C., B.Sc., A.M.I.E.E.	7	6
Changeover of D.C. Supply Systems to the Standard System of A.C. Distribution. By S. J. Patmore, A.M.I.E.E.	3	6
Direct Current Machines, Performance and Design of. By A. E. Clayton, D.Sc., M.I.E.E.	16	0
Electric Clocks, Modern. By Stuart F. Philpott, A.M.I.E.E. Second Edition	7	6
Electric Lighting and Power Distribution. By W. Perren Maycock, M.I.E.E. Ninth Edition, thoroughly revised by C. H. Yeaman. In two volumes . . . . . *Each*	10	6
Electric Motor Control Gear, Industrial. By W. H. J. Norburn, A.M.I.E.E.	10	6
Electric Plant, Protection of (Modern Developments). By F. P. Stritzl, D.Sc.Tech. (Vienna)	15	0

Electrical Engineering, etc.—contd.

	s.	d.
Electric Traction. By A. T. Dover, M.I.E.E., Assoc. Amer.I.E.E. Second Edition	25	0
Electric Wiring, Fittings, Switches, and Lamps. By W. Perren Maycock, M.I.E.E. Sixth Edition. Revised by Philip Kemp, M.Sc., M.I.E.E., etc.	10	6
Electric Wiring Tables. By W. Perren Maycock, M.I.E.E., Seventh Edition Revised by F. C. Raphael, M.I.E.E.	3	6
Electrical Contracting, Organization, and Routine. By H. R. Taunton	12	6
Electrical Engineering, Classified Examples in. By S. Gordon Monk, M.Sc. (Eng.), B.Sc., A.M.I.E.E. In two parts.		
*Vol. I. Direct Current. Fourth Edition	2	6
*Vol. II. Alternating Current. Fourth Edition	4	0
Electrical Engineering, Experimental. By E. T. A. Rapson, A.C.G.I., D.I.C., M.Sc. (Eng.) London, etc. Second Edition	3	6
Electrical Measurements and Measuring Instruments. By E. W. Golding, M.Sc.Tech., A.M.I.E.E., M.A.I.E.E. Second Edition	20	0
Electrical Measuring Instruments, Industrial. By Kenelm Edgcumbe, M.Inst.C.E., M.I.E.E., F.Inst.P., and F. E. J. Ockenden, A.M.I.E.E. Third Edition	25	0
Electrical Technology. By H. Cotton, M.B.E., D.Sc., A.M.I.E.E. Third Edition	12	6
Electrical Terms, A Dictionary of. By S. R. Roget, M.A., A.M.Inst.C.E., A.M.I.E.E. Third Edition	8	6
Electrical Wiring and Contracting. Edited by H. Marryat, M.I.E.E., M.I.Mech.E. In seven volumes . *Each*	6	0
Electricity, Foundations of Technical. By E. Mallett, D.Sc., M.Inst.C.E., M.I.E.E., F.Inst.P., and T. B. Vinycomb, M.C., M.A., F.Inst.P.	5	0
Generation, Transmission and Utilization of Electrical Power. By A. T. Starr, M.A., Ph.D., B.Sc., A.M.I.E.E.	18	0
Instrument Transformers: Their Theory, Characteristics and Testing. By B. Hague, D.Sc. (Lond.), Ph.D. (Glas.), F.C.G.I., etc.	35	0
Meter Engineering. By J. L. Ferns, B.Sc. (Hons.), A.M.C.T. Second Edition	10	6
Photoelectric Cell Applications. By R. C. Walker, B.Sc. (Lond.), and T. M. C. Lance, Assoc.I.R.E. Third Edition	12	6
Power Wiring Diagrams. By A. T. Dover, M.I.E.E., A.Amer. I.E.E. Third Edition	6	0
Switchgear, Outdoor High Voltage. By R. W. Todd, A.M.I.E.E., Assoc.A.I.E.E., and W. H. Thompson, A.M.I.E.E.	42	0
Symmetrical Component Theory, Elements of. By G. W. Stubbings, B.Sc. (Lond.), F.Inst.F., A.M.I.E.E.	5	0

TELECOMMUNICATIONS

	s.	d.
Electric Circuits and Wave Filters. By A. T. Starr, M.A., Ph.D., A.M.I.E.E. Second Edition	21	0
Radio Communication, Modern. By J. H. Reyner. In two volumes—Vol. I. Sixth Edition, 5s. Vol. II. Second Edition, 7s. 6d.		
Radio Engineering, Problems in. By E. T. A. Rapson, A.C.G.I., D.I.C., A.M.I.E.E. Third Edition	3	6
Radio Receiver Circuits Handbook. By E. M. Squire	4	6
Radio Receiver Servicing and Maintenance. By E. J. G. Lewis. Second Edition	8	6
Radio, Short-Wave. By J. H. Reyner	8	6
Radio Upkeep and Repairs for Amateurs. By Alfred Witts, A.M.I.E.E. Third Edition	5	0
Superheterodyne Receiver, The. By Alfred T. Witts, A.M.I.E.E. Third Edition	3	6
Telegraphy. By T. E. Herbert, M.I.E.E. Sixth Edition	20	0
Telegraphy and Telephony, Arithmetic of. By T. E. Herbert, M.I.E.E., and R. G. de Wardt	5	0
Telephone Handbook and Guide to the Telephonic Exchange, Practical. By Joseph Poole, A.M.I.E.E. (Wh.Sc.). Seventh Edition	18	0
Telephony. By T. E. Herbert, M.I.E.E., and W. S. Procter, A.M.I.E.E. In two volumes.		
Vol. I. Manual Switching Systems and Line Plant. Second Edition	20	0
Vol. II. Automatic Telephony	20	0
Television Engineering. By J. C. Wilson	30	0
Television Optics. By L. M. Myers. Second Edition	30	0
Television Reception Technique. By Paul D. Tyers	12	6
Wireless, A First Course in. By "Decibel"	4	0

MATHEMATICS AND CALCULATIONS FOR ENGINEERS

	s.	d.
Calculus for Engineers and Students of Science. By John Stoney, B.Sc., A.M.I.Min.E., M.R.San.I. Second Edition	6	0
Exponential and Hyperbolic Functions. By A. H. Bell, B.Sc.	3	6
Graphs of Standard Mathematical Functions. By H. V. Lowry, M.A.	2	0
Logarithms for Beginners. By C. N. Pickworth, Wh.Sc. Eighth Edition	1	6
*Logarithms Simplified. By Ernest Card, B.Sc., and A. C. Parkinson, A.C.P. Second Edition	2	0
Mathematics, Elementary Practical. In three volumes, each 5s. By E. W. Golding, M.Sc., Tech., A.M.I.E.E., and H. G. Green, M.A. Book I. First Year. Book II. Second Year. Book III. Third Year.		

Mathematics and Calculations for Engineers—contd.

	s.	*d.*
MATHEMATICS, PRACTICAL. By Louis Toft, M.Sc. (Tech.), and A. D. D. McKay, M.A.	12	6
NOMOGRAM, THE. By H. J. Allcock, B.Sc., A.M.I.E.E., A.M.I.Mech.E., and J. R. Jones, M.A., F.G.S.	10	6

MISCELLANEOUS TECHNICAL BOOKS

ACOUSTICAL ENGINEERING. By W. West, B.A., A.M.I.E.E.	15	0
ENGINEERING ECONOMICS. By T. H. Burnham, B.Sc. Hons. (Lond.), B.Com. (Lond.), F.I.I.A., A.M.I.Mech.E., M.I.Mar.E. In two volumes, each 8s. 6d. Book I. Elements of Industrial Organization and Management. Book II. Works Organization and Management.		
ENGINEERING INQUIRIES, DATA FOR. By J. C. Connan, B.Sc. A.M.I.E.E., O.B.E.	12	6
FOUNDRY ORGANIZATION AND MANAGEMENT. By James J. Gillespie	12	6
MOTOR BOATING, THE SAFETY WAY IN. By A. H. Lindley-Jones	5	0
SAILING CRAFT, SMALL. By John F. Sutton, M.Sc. (Eng.), A.M.I.M.E. Second Edition	5	0
SCIENCE, THE MARCH OF. A First Quinquennial Review, 1931–35. By Various Authors. Issued under the authority of the Council of the British Association for the Advancement of Science	3	6
SHOE REPAIRER'S HANDBOOKS. By D. Laurence-Lord. In seven volumes . . . *Each*	3	6
TEACHING METHODS FOR TECHNICAL TEACHERS. By J. H. Currie M.A., B.Sc., A.M.I.Mech.E.	2	6
WITH THE WATCHMAKER AT THE BENCH. By Donald de Carle, F.B.H.I. Third Edition	8	6
WORKS ENGINEER, THE. By W. R. J. Griffiths, M.Inst.F., A.M.S.W.I.E. In Collaboration with W. O. Skeat, B.Sc. (Eng.), G.I.Mech.E., etc.	21	0

PITMAN'S TECHNICAL PRIMERS

Each in foolscap 8vo, cloth, about 120 pp., illustrated	2	6

The Technical Primer Series consisting of about 40 titles is intended to enable the reader to obtain an introduction to whatever technical subject he desires. Please send for complete list of titles, sent post free on request.

COMMON COMMODITIES AND INDUSTRIES SERIES

Each book in crown 8vo, cloth, with many illustrations, etc.	3	0

In each of the handbooks in this series a particular product or industry is described by an expert writer and practical man of business. Write for complete list of titles, sent post free on application.

MADE IN GREAT BRITAIN AT THE PITMAN PRESS, BATH
(D.6301)